ENERGY RESEARCH, VOL. 1, 289–298 (1977)

VENTILATION: A BEHAVIOURAL APPROACH

G. W. BRUNDRETT

Electricity Council Research Centre, Capenhurst, Chester, U.K.

SUMMARY

Behavioural studies of the window-opening habits of families in one hundred and twenty three houses show a strong seasonal pattern. During winter window opening is closely related to moisture level in the external air. In summer it is more closely linked to mean daily temperature. There are wide differences between families, with larger families having more open windows. Re-examination of ventilation criteria suggests three seasons, one in deep winter which needs minimum adequate air for body odour removal, the second in spring/autumn for controlling moisture and the third in summer for cooling.

KEY WORDS Ventilation Behavioural study

1. INTRODUCTION

Energy calculations for space heating involve two heat-loss mechanisms. The first is heat conducted through the building fabric. The second is heat loss through casual air infiltration. Recent improvements in fabric insulation make this ventilation factor proportionately more important since it can represent 50 per cent of the total loss.

In given weather conditions the minimum air change rate is controlled by the size and disposition of gaps in the building envelope, particularly those around doors and windows. Surveys of modern houses by Warren, 1975, revealed air change rates of 0·45–1·25/h in average winter weather conditions when the house windows and doors were closed. In practice the occupants of houses often find they prefer more ventilation than this minimum and they achieve it by opening the windows. Dick and Thomas, 1951, observed the windows opened in twenty occupied experimental houses. They showed a linear relationship between the number of windows open and the mean outdoor temperature (Figure 1). This accounted for 70 per cent of the observed variance in the number of windows open. A further 10 per cent variance could be attributed to wind speed with higher wind speeds associated with smaller numbers of open windows. The houses were carefully calibrated and the air change rate was linearly linked to outdoor temperature. However, these houses only contained different types of local heating and did not include central heating.

Detailed field trials on modern central heating equipment were undertaken at Bromley over the 1968/69 heating season. While no window observations were recorded, estimates of ventilation rates were made from energy balance considerations. This suggested a very similar user pattern to that of the earlier study. However, a more positive identification of the modern housewife's window-opening behaviour was needed. This paper describes the experiment to quantify and understand this behaviour.

2. OUTLINE OF SURVEY

The window-opening pattern which a family adopts in a house was expected to be influenced by two major factors. One was the weather, the other was the personal characteristics of that family. To identify the key features in these two independent factors we needed three surveys. The first and most important was the regular observation of a number of houses over a long period of time. The second was the systematic recording of the weather over the same period. The third was an interview with the husband

Received 1 May 1977

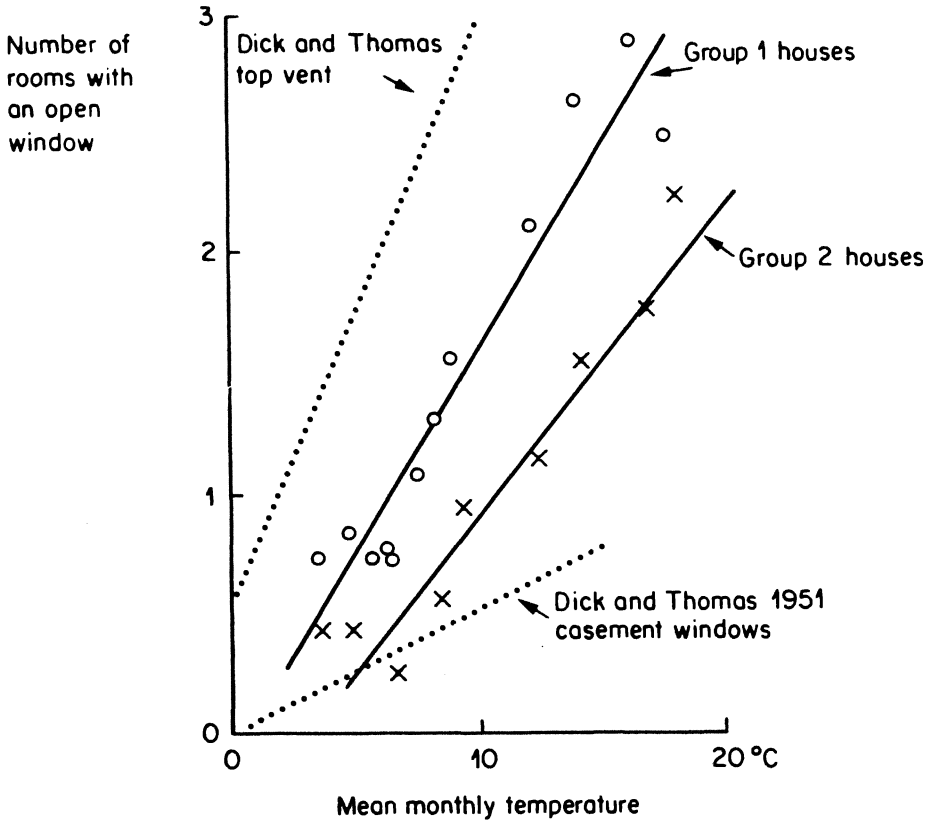

Figure 1. Relationship between open windows and temperature

or housewife in each family. This was necessary to ascertain basic parameters such as the number and age of people in the house, and whether they smoked and to record habits such as whether they were in the house during the day or not. Finally such an interview could also elicit the person's own opinions and reasons for opening windows.

The analysis of the window-opening observations was undertaken in two parts. The changes in average window-opening behaviour from day to day were correlated with the weather factors. In contrast to this the differences between families were analyzed in terms of their personal characteristics.

The houses in this survey were located at Connahs Quay. Two estates were chosen to represent modern housing practice. Both groups were built between four and ten years ago. The sites were adjacent to each other. Weather data was recorded at Capenhurst some six miles north-east of the site. The open windows were recorded each weekday for a year from October 1974 to September 1975 in all of the houses. Observations were equally divided between mid-morning and mid-afternoon. Since the size, number and shape of the windows differed widely between houses the survey noted which rooms had an open window. For convenience this was the unit measure of open windows.

The householders were individually informed of the experiment at the start of monitoring. After six to nine months each householder was invited to give his or her views on window opening and to supply details about their family.

3. BACKGROUND DATA OF THE PEOPLE AND THEIR HOUSES

A high proportion of the people (82 per cent) living in these houses were interviewed. This showed the two housing groups to contain people similar in age and family size. Both groups were predominantly in the younger part of the population with more than three-quarters of them under 34 years old.

Table I. Background data of the people and their houses

(a) Houses

		House Group 1 No.	%	House Group 2 No.	%	Total
Type	Detached	15*	37	4*	5	19
	Semi-detached	26	63	18	22	44
	Town houses	0	0	60	73	60
	Total	41	100	82	100	123

* four were four bedroom, all other houses were three bedroom.

(b) Windows: estimated sizes and number

Room	Group 1 Av. windows/room Large*	Medium*	Small*	Group 2 Av. windows/room Large	Medium	Small
Lounge	0·51	0·49	0·49	1·0	0·61	0·16
Dining room	0·54	0·49	1·0	0·88	0·13	0·07
Kitchen	0	0·95	0·54	0·67	0·33	0·15
Bedroom 1	0·51	1·34	0·98	0·84	0·72	0·13
Bedroom 2	0·51	0·49	0·49	0·54	0·51	0
Bedroom 3	0	1·0	1·0	0·90	0·74	0
Bathroom	0	1·44	0·98	0·66	0·34	0·05

* large is greater than $\frac{1}{3}m^2$, medium is approx. $\frac{1}{5}m^2$, small is approx. $\frac{1}{10}m^2$.

(c) Family details (of those who were interviewed)

		House Group 1 No.	%	House Group 2 No.	%	Total No.
Size of family	one	1	3	1	1	2
	two	5	15	14	21	19
	three	8	24	18	26	26
	four	13	39	26	38	39
	five	6	18	6	9	12
	six	0	0	2	3	2
	seven	0	0	1	1	1
	Total	33	100	68	100	101
Social groupings	AB	6	18	3	4	9
	C1	9	27	11	16	20
	C2	12	36	25	37	37
	D	6	18	28	42	34
	Total	33	100	67	100	100
Age of respondent	16–24 yrs	8	24	16	24	24
	25–34 yrs	17	52	44	65	61
	35–44 yrs	6	18	6	9	12
	45–54 yrs	2	6	1	1	3
	55–64 yrs	0	0	1	1	1
	65+ yrs	0	0	0	0	0
	Total	33	100	68	100	101
Women respondents	full-time/ h/wife	20	83	30	73	50
	pt-time/ employed	3	12	3	7	6
	full-time/ employed	1	4	8	20	9
	Total	24	100	41	100	65

There was only a small proportion of older people and none above retirement age. Social rankings for Group 1 were spread evenly, while Group 2 were weighted towards C2/D. More of the Group 2 housewives went out to work.

The types of houses differed between the two Groups. Group 1 was essentially semi-detached (26) with some detached houses (15). Group 2 comprised terraced town houses (73) with some semi-detached (18) and a few detached (4). The architect's choice of windows differed between the two groups. Group 1 had a much higher proportion of smaller windows than Group 2.

These results are summarized in Table I.

4. WEATHER SENSITIVITY

The observations showed a strong seasonal pattern with windows progressively closing with the approach of winter and then re-opening with the warmer weather. It was common to find open windows during the heating season (Table II). Approximately twice as many rooms had open windows in the Group 1 houses as in the Group 2 houses.

Table II. Monthly averages for weather and window opening. Connahs Quay 1974/75

Month	Group 1	Group 2	Mean temp. t °C	Av. humidity g/kg dry air	Av. temp. swing Δt°C	Av. wind speed m/s	Av. cloud cover overcast = 1	Rainfall mm
Oct.	1·31	0·56	8·7	6·4	6·9	3·2	0·5	4
Nov.	0·71	0·29	6·0	5·1	5·2	4·2	0·5	5
Dec.	0·71	0·25	6·8	5·4	6·0	6·9	0·6	2
Jan.	0·74	0·33	6·5	5·3	6·1	4·7	0·5	2
Feb.	0·73	0·42	3·7	5·0	7·2	1·7	0·4	2
Mar.	0·82	0·44	5·0	5·4	7·5	5·4	0·5	2
Apl.	1·09	0·54	7·9	6·9	8·2	6·1	0·5	2
May	1·64	0·91	9·6	6·4	10·0	5·1	0·4	2
June	2·61	1·53	14·8	8·7	14·6	5·5	0·3	1
July	2·89	1·76	17·2	8·8	16·8	4·6	0·4	2
Aug.	2·49	2·23	18·5	11·0	18·7	5·3	0·3	2
Sept.	2·10	1·12	12·9	7·8	12·6	5·5	0·4	2

The relationship of open windows to daily mean external temperature was similar to that of Dick and Thomas (Figure 1). However, for Britain there is a strong link between mean daily temperature and mean daily humidity. The window-opening behaviour could therefore be temperature or moisture motivated (Figure 2).

Correlation of the window-opening behaviour with winter weather showed Group 1 to be associated with mean daily temperature swing and to a small extent by wind speed. Group 2 was associated primarily with external moisture levels, to sunshine and wind, and to a small extent to daily temperature swing. Selecting those houses where the housewife did not go out to work resulted in a similar result to those houses in Group 2, i.e. more strongly linked to moisture than temperature, Table III.

The distribution of rooms containing open windows is shown in Figure 3. Bedrooms are the most common places for open windows. Other rooms, except kitchens, follow the same pattern though to a small magnitude. Kitchens are much less sensitive to the weather.

A similar analysis for the summer weather showed mean daily temperature to be the main associated factor for all three categories of Group 1, Group 2 and those houses with the housewife at home.

People's own assessment of which window they open and when are in agreement with the observations except for the kitchen. Their reports are summarized in Figures 4–7. The disagreement between observed kitchen and reported kitchen behaviour is probably due to the survey times. No observations were made around meal times when the kitchen use may be expected to be at a maximum.

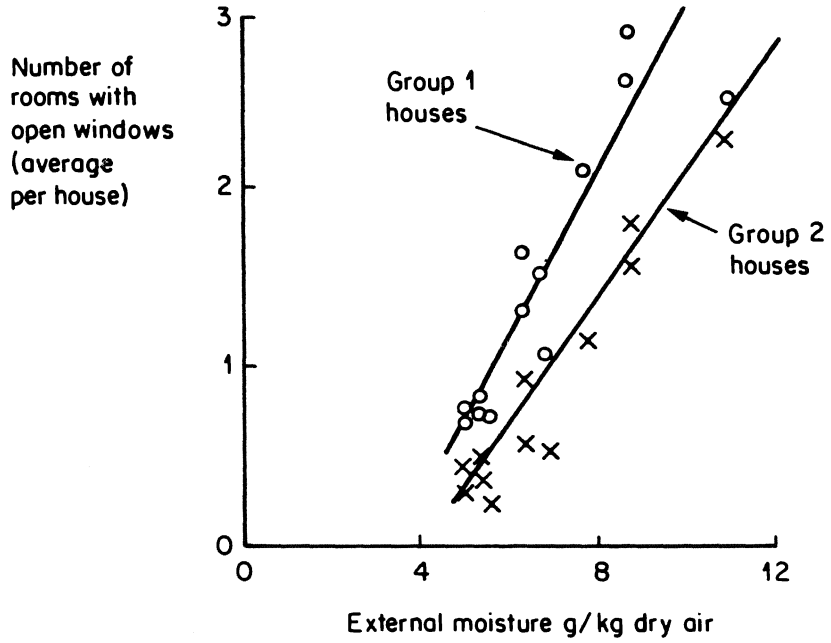

Figure 2. Relationship between open windows and moisture

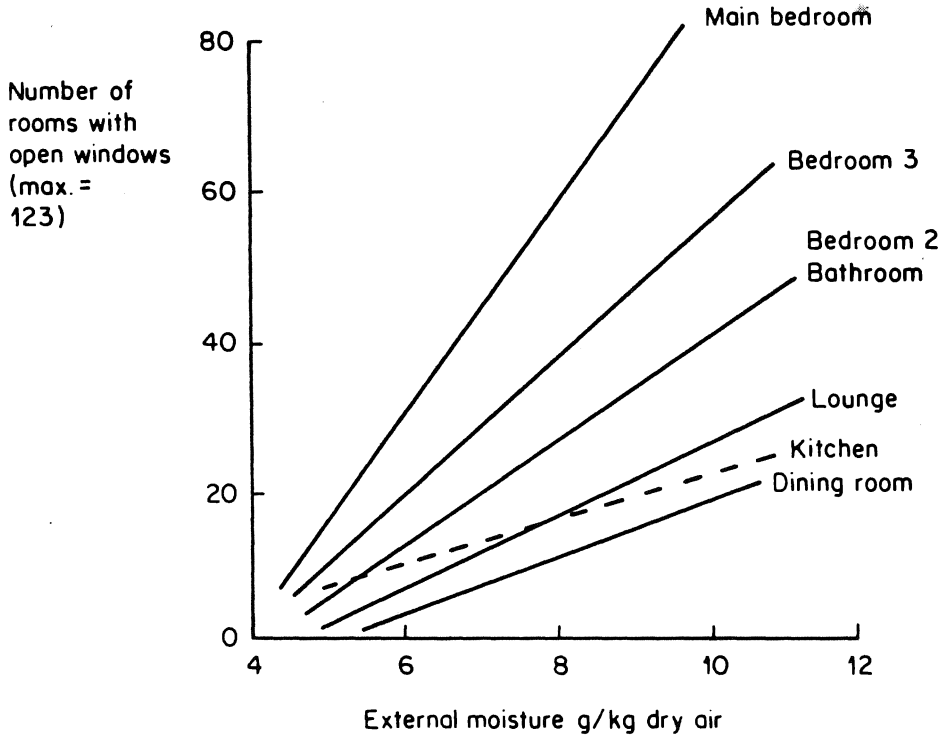

Figure 3. Which rooms have open windows

Table III. Winter: multiple correlation of window opening with weather (October–April inclusive: 127 days)

Group	No. of houses	Equation for daily no. of rooms with open window/house (in order of importance)	Multiple correlation coefficient r	Statistical significance*
House Group 1	41	constant −0·02 +0·1 × mean temperature (°C) +0·06 × temperature swing (°C) −0·02 × wind speed (m/s)	0·68	$p < 0·01$
House Group 2	82	constant −0·04 +0·09 × humidity (g/kg dry air) −0·02 × cloud cover (tenths) −0·1 × wind speed (m/s) +0·02 × temperature swing (°C)	0·67	$p < 0·01$
All houses with housewife at home	53	constant 0·22 +0·16 × humidity (g/kg dry air) −0·04 × cloud cover (tenths) +0·04 × temperature swing (°C)	0·64	$p < 0·01$

*F ratio test, significance of extra factor.

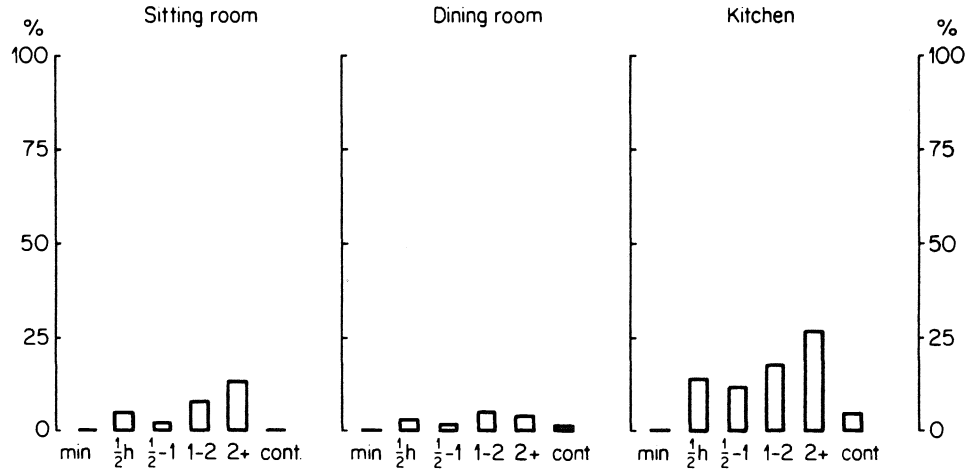

Figure 4. Downstairs windows: people's own report on duration open

Figure 5. Upstairs windows: people's own report on duration open

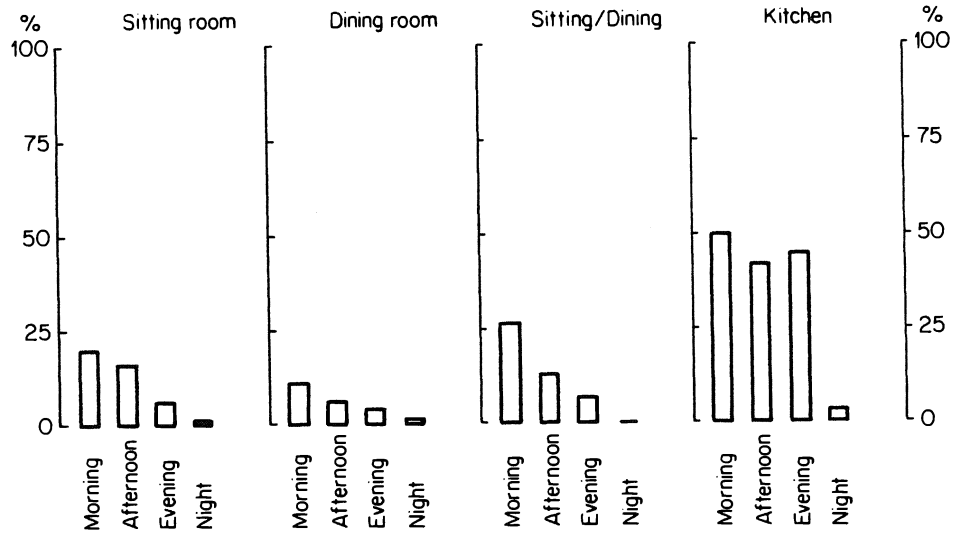

Figure 6. Downstairs windows: people's own report of time of day open

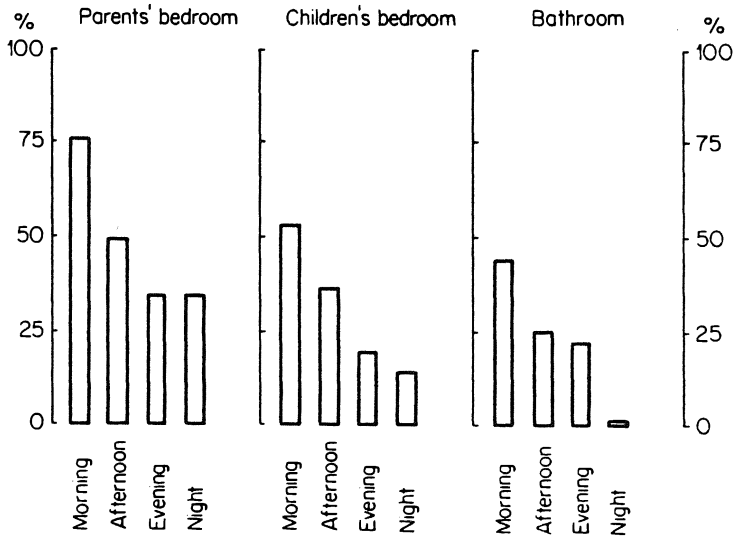

Figure 7. Upstairs windows: people's own report of time of day open

5. FAMILY FACTORS

Two important family characteristics influenced window-opening behaviour. The first was whether the housewife had a job. Those housewives out at full-time employment had only half the windows open of those who stayed at home.

The second characteristic was size of the family. Analysis of the habits of those housewives who stayed at home showed that the number of rooms with open windows increased with the number in the family.

These relationships are summarized in Table IV.

Each family who believed windows were opened in winter was given the opportunity of saying why this may be. The distribution of these spontaneous reasons is given in Table V.

the window-opening behaviour being more closely linked with mean daily temperature than with humidity during summer.

Borel, 1974, has already proposed a two-season controlled ventilation system. Winter needs for body odour control are separated from the summer needs of cooling. Perhaps the introduction of a third element is particularly appropriate for houses, namely moisture control. The principle is outlined in Figure 8.

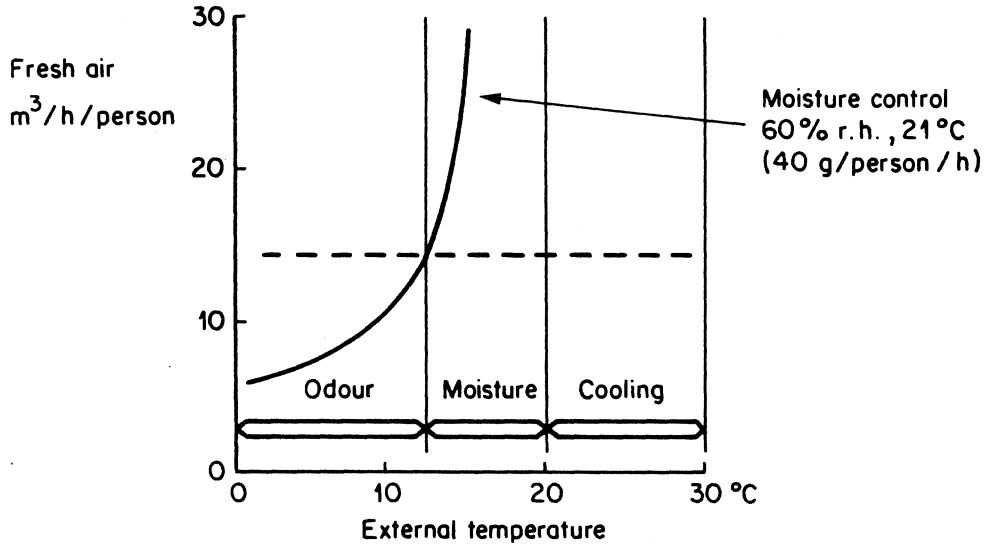

Figure 8. Proposed ventilation seasons

7. CONCLUSIONS

1. It is common to find open windows in Britain throughout the year. The number of open windows is strongly linked to weather with external moisture being most clearly associated in winter and mean temperature in summer.

2. The most popular rooms to have an open window are the bedrooms. The windows in other rooms are much less often open, though with the exception of the kitchen they follow similar behaviour. The kitchen windows are more often open in the coldest weather.

3. The two family factors which influence window-opening behaviour are whether the housewife goes out to work and the size of family. Houses where the housewife is at home are much more likely to have an open window. Houses which contain larger families are also more likely to have an open window.

4. The energy implications of this behaviour require more research.

ACKNOWLEDGEMENTS

The success of this experiment is due to the large amount of assistance provided by many colleagues. Specifically, the weather data was generously supplied by British Nuclear Fuels Limited; the questionnaire design was drawn up with Mr. Ian Griffiths of Atkins Research and Development; the family data was skilfully collected partly through Atkins R. & D. and partly through Gordon Simmons Fieldwork Limited; and the window observations were patiently made by staff of the Electricity Council Research Centre. All the computer analysis of results was obligingly done by Mr. J. Waddington of the Mathematics Section, ECRC.

Finally, I must acknowledge the co-operation and tolerance of the householders involved in the project since without it the experiment could not have proceeded.

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