ENERGY EFFICIENT DOMESTIC VENTILATION SYSTEMS FOR ACHIEVING ACCEPTABLE INDOOR AIR QUALITY

3rd AIC Conference, September 20-23 1982, London, UK

PAPER 10

THE VENTILATION PERFORMANCE OF HOUSES - A CASE STUDY

O'SULLIVAN, P. AND JONES, P.J.

The Welsh School of Architecture (Research and Development),
University of Wales Institute of Science and Technology,
24, St. Andrews Crescent, Cardiff, South Wales, CF1 3DD.

In an energy efficient house with high insulation standards, the ventilation system must be designed. The main design criteria is that the ventilation rates be maintained close to the required minimum level throughout the heating season. Yet because so little understanding was required and achieved about the performance of natural ventilation in traditional houses, it was, in the mid-1970's, difficult to know where to start from, to design for natural ventilation in energy efficient houses. The conventional wisdom at the time was that low infiltration rates were achieved by using high performance (energy efficient) components and sealing up as much as possible of the gaps and cracks in the outer wall, and then to rely on the remaining gaps to provide the minimum ventilation level by infiltration. Not surprisingly, in many cases, this method did not work, stuffiness, stagnation and condensation occurred and the initial low energy houses did not achieve their 'ventilation' aspirations. From the results of these early houses, it was argued that designing a ventilation system for a naturally ventilated energy efficient house was not simply a matter of designing methods for reducing the whole-house ventilation rate, say from 4 ac/h to .5 ac/h, by applying a 'blanket' of sealing measures. Adequate ventilation is an essential component of the internal physical environment and a minimum standard must be maintained, not only in the house as a whole but distributed in a way appropriate to the requirements of individual spaces. The ventilation performance of a house therefore is not only determined by the distribution of cracks and the level of window opening, it is also fundamentally a product of the spatial layout. In order therefore to arrive at a design methodology for natural ventilation, air flow patterns within the house envelope must be measured and understood.

For this reason, ventilation studies were included in,and formed an important part of the Abertridwr Project[1,2,3,4], the main objective of which was to assess the cost benefits of additional levels of insulation. To this end two groups of houses were used, 19 insulated to Part F of the Building Regulations 1975, and 20 insulated to what is now Part F, 1982. In the design of these houses, the ventilation was achieved in the traditional manner by choosing good quality components and draught-stripping the doors and windows. The houses were therefore ideally suited for a case study on the ventilation performance of highly insulated energy efficient houses.

This paper briefly describes the Abertridwr Project as a whole. It then describes the sequence of ventilation experiments within the project carried out over a period of four and a half years and summarizes the major results.

It describes how as a result of the first stage of ventilation experiments, modifications were made to a number of houses, in that 'trickle' ventilators were installed. The results of these modifications are next discussed.

Finally, conclusions are drawn, and suggestions made concerning a methodology for the design of natural ventilation systems in low energy houses.

2. DESCRIPTION OF ABERTRIDWR PROJECT

The project involved the physical and social monitoring of thirty nine occupied houses sited in Abertridwr, South Wales.

The houses are three-bedroomed, terraced (Fig.1), owned by the Housing Association, and are heated by gas fired, low-pressure central heating systems.[1,2,3,4]

The project had two main objectives:

1. To assess the effects of better insulation standards in houses together with appropriately smaller heating systems in providing comfort conditions at lower energy costs.*

2. To measure the operating efficiencies of domestic gas-fired central heating systems.**

To achieve these objectives, twenty houses (Better Insulated [BI] houses= were designed with higher standards of insulation compated with the remaining nineteen houses (the control houses) in the form of:-

(a) Dry lining wall insulation (a method considered appropriate to the exposed conditions)

(b) Double thickness of roof insulation

(c) A border slab of floor insulation embedded in the concrete base.

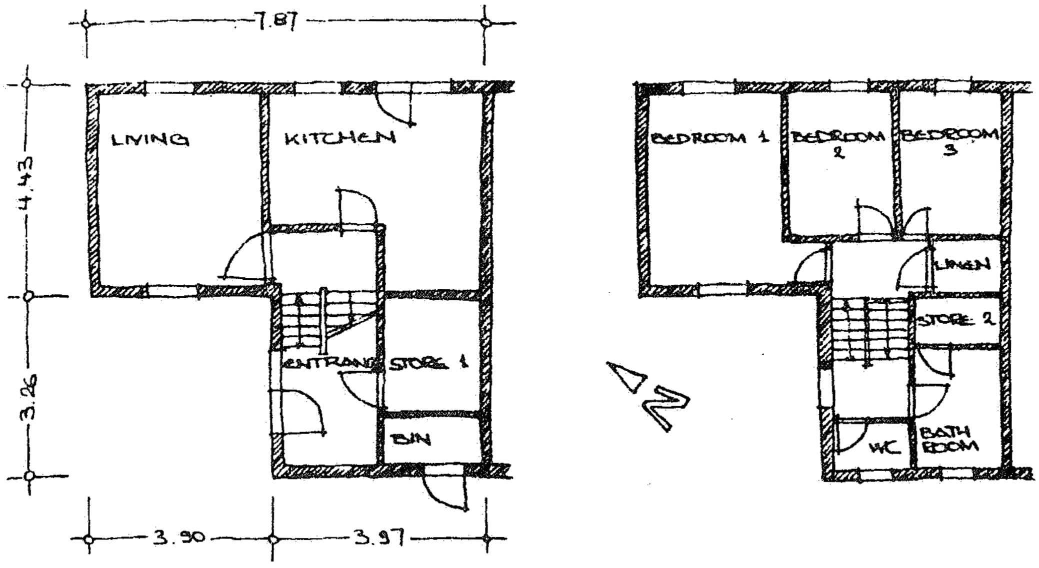
The overall steady state fabric heat loss of the test houses is reduced by approximately 30% compared to the control houses.

In addition, the heating system in the test houses is appropriately smaller, employing an 8.3 kw boiler compared with the 14.7 kw boiler of the control houses. The number of the radiators was also matched to the reduced fabric losses in the BI houses, there being originally no radiators in the bedrooms. However, the controls are the same in both BI and control houses. A programmable clock allows two 'on' periods per day. Ther is a room thermostat in the living room which controls the boiler and pump. All other radiators have thermostatically controlled radiator valves fitted. The heating system is also used, in both groups, to provide domestic hot water.

---

* Sponsored by Department of Environment, Housing Development Directorate

** Sponsored by Science and Engineering Research Council



PLAN : LEVELS 1+2

PLAN: LEVELS 3+4

SIDE ELEVATION

ELEVATION TO FOOTPATH

FIGURE 1 ABERTRIDWR HOUSE - PLAN AND ELEVATION

Finally, traditional draught-stripping measures have been employed in both BI and control houses to reduce ventilation losses through infiltration.

Physical data has been collected by means of the continuous monitoring of energy inputs, internal air temperatures, external climate and boiler efficiency parameters. Values are stored on a five-minute time scale though the measurement associated with boiler efficiency are measured every twelve seconds and then averaged over the five minute period. In the order of 800 measurements are stored every five minutes.

Social data is collected by means of interviews with the occupants concerning the daily patterns of occupation and 'energy use' of the houses. In addition, information has been collected concerning comfort conditions, knowledge of the control system, previous heating experience, condensation problems and faults with the heating system.

Additional information has been provided by:

(a) Measurements of ventilation rates

(b) Thermography surveys*

(c) Experiments in unoccupied houses

One BI house (the test house) has been occupied by the project team for the duration of the project and this house has been used to carry out 'controlled' experiments.

The project was in full operation from September 1980 (although monitoring and experiments had proceeded on a reduced sample since 1978) and ended in September 1981. (A more detailed description of the project and initial results are reported elsewhere[1,2,3,4]).

Since September 1981 the Abertridwr houses, together with the monitoring system, have been used for two further projects. One involving a study of incidental gains in houses** and the other demonstrating the performance of trickle ventilators***. The later project is described in Section 5 of this paper.

3. VENTILATION EXPERIMENTS

3.1 Measurement Programme

The first objective of the ventilation measurements programme, carried out under the Abertridwr Project, was to determine the ventilation characteristics of the Abertridwr Houses.

As our understanding of the ventilation performance of the houses developed over the four and a half years and as modifications were carried out to the ventilation system, the objectives of the experiments changed in their emphasis.

---

* Thermography surveys were carried out by British Gas

** An Investigation into the Effective Use of Incidental Heat Gains in Dwellings (funded by SERC)

*** Monitoring the Performance of Trickle Ventilrators (funded by BRECSU)

In measuring the ventilation characteristics of the houses the following experimental techniques have been used by the organisations concerned (Building Research Establishment [BRE], British Gas [BG], and UWIST).

To determine the whole-house and room infiltration rates, Tracer Decay methods were used by BRE, while BG used their Autovent technique together with a limited number of Tracer Decay Tests.

Conventional pressurization techniques have been used to determine the leakage characteristics of the houses. In addition a method developed by BG was used (by BG) for determining the area leakage distribution[5].

The first experiments were carried out by BRE in March 1978 and their objectives were to assess the general ventilation characteristics of the houses. They performed Pressurization measurements in eight houses, four BI houses and four control, and extensive Tracer Decay measurements in one of the BI houses (house 2).

In January 1979 BRE performed further leakage tests on three of the houses that had been tested the previous year, the objectives being to obtain a measure of any increases in leakage over the first year of occupancy.

British Gas carried out ventilation experiments in February and March 1980. They included twelve houses in their programme. In these twelve houses they performed Pressurization tests and a small number of Tracer Decay tests. In one of the BI houses (the test house - house 1) they performed extensive Tracer Decay tests using the Autovent technique.[5] The objective of this programme of experiments was to give a further insight into the ventilation characteristics of the houses covering a larger sample than had previously been used, and again to measure any change in leakage with age. In particular, the Autovent technique enables the ventilation patterns of a house to be investigated.

As a result of this first series of experiments trickle vents were installed in the test house and 2 other houses in order to try and produce an improved ventilation distribution pattern, and in an attempt to alleviate the problems of condensation.

In February 1981 British Gas carried out ventilation and leakage distribution measurements on the test house in order to determine what differences the trickle ventilators made to the house ventilation pattern.

In July 1982 UWIST carried out air leakage tests on nine of eighteen houses which had had trickle ventilators installed during February, 1982, to measure the air leakage of the houses with trickle ventilation. This last set of measurements formed part of a new project, demonstrating the performance of trickle ventilation.

Table 3.1 summarizes the programme of ventilation experiments performed in the Abertridwr houses.

TABLE 3.1 SUMMARY OF EXPERIMENTAL PROGRAMME

Date	Organization*	No. of Houses Infil.	No. of Houses Leakage
March 78	BRE	1	8
Jan. 79	BRE		3
Feb/Mar. 80	BG	12 (1 Autovent)	12
Feb. 81	BG	1 (Autovent)	1
July 82	UWIST		9

*Measurements were performed by Building Research Establishment [BRE], British Gas [BG], and UWIST.

3.2 Results

(a) Air Leakage Measurements

Four whole-house air leakage surveys were carried out over a four and a half year period. The results are summarized in Table 3.2.

TABLE 3.2 SUMMARY OF WHOLE HOUSE AIR LEAKAGE TESTS (m^3/s)

Where whole house infiltration rates were available they have been included in brackets (ac/h). Infiltration rates for houses, other than house 1 in 1980 are each from a single Tracer Decay test.

	House	Mar 78 @ 50pa	Jan 79 @ 50pa	Feb/Mar 80 @ 20pa	Feb/Mar 80 @ 50pa	July 82 (vents closed) @ 20pa	July 82 (vents closed) @ 50pa
B.I.	1	0.45	0.95	0.52	0.97(0.48)	0.55	0.91
	2	0.44(0.49)		0.34	0.64(0.53)	0.48	0.79
	3	0.57	1.0	0.54	0.93(0.40)	0.52	0.99
	4	0.54	0.9	0.43	0.80(0.36)	0.44	0.79
	5					0.47	0.81
	6					0.5	0.88
	7			0.33	0.59(0.50)		
	8			0.35	0.60(0.34)		
	9			0.32	0.57(0.44)		
	10			0.36	0.65(0.44)		
	11			0.45	0.80(0.49)		
	12			0.44	0.75(0.55)		
CONTROL	13					0.38	0.78
	14					0.36	0.71
	15	0.37		0.46	0.78		
	16	0.40					
	17	0.40		0.39	0.68(0.51)		
	18	0.37					
	19					0.36	0.69
	20					0.37	0.71

The 1978 BRE survey was carried out shortly after the houses were constructed. The results show that the control houses are on average (21%) 'tighter' than the B.I. houses. This was attributed to the dry-lining construction of the B.I. houses.

Further measurements by BRE on three of the houses in 1979 showed a dramatic increase in whole-house leakage during the first year of occupation. This was probably caused by the drying out of timbers etc., and warping of doors and windows.

Leakage measurements taken over the following three years show surprisingly little change in levels.

Room leakage measurements were carried out by BG in 1980 on house 1. (The results are presented in Figure 4.1). As each room was measured the rest of the house was maintained at the same pressure, so that the results represent only the leakage to the outside. The landing, hall and bathroom exhibit the largest leakages. This is not surprising if the results of 1978 BRE component leakage measurements of house 2 are considered (Fig.3.1)

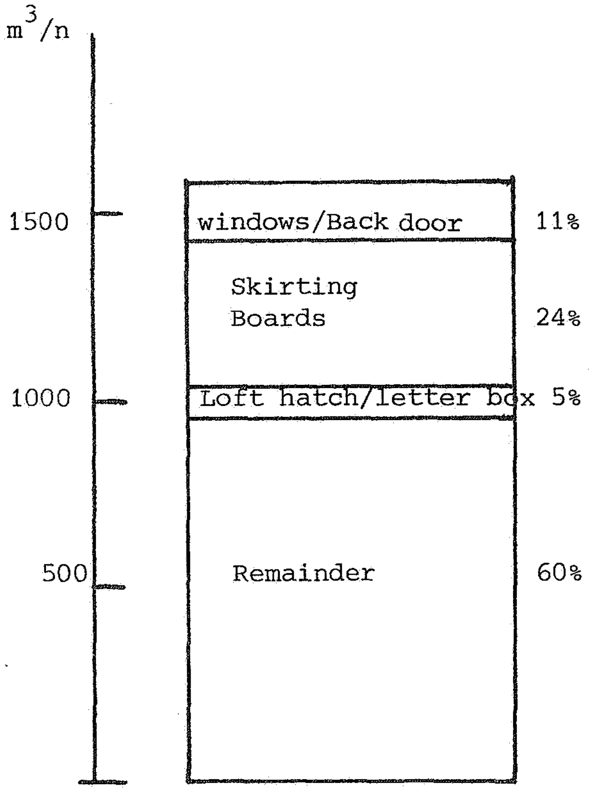


FIG. 3.1 Distribution of Air Leakage in house 2 (@ 50pa)

The majority of leakage was attributed to service entry, and general cracks. The bathroom has a large amount of pipework entering. The hall and landing have a relatively large amount of external wall area plus the front door which, from measurements made, has the largest single component crack area. Observation of air flow patterns, using smoke detection, have identified the predominant air flow route to be in through the hall and sometimes the bathroom and out through the bathroom, landing area and bedrooms.

Although the BG leakage tests were performed on different houses it is, from experience with the house construction, believed that the major components of leakage will be the same.

(b) Air Infiltration Measurements

The results for average infiltration rates, from the 1978 and 1980 measurements are presented in Table 3.3 for two houses (houses 1 and 2), in which extensive measurements were carried out. Values of whole house infiltration rate for ten other houses have been included (bracketted) in Table 3.2, although they were calculated each from a single decay test and will therefore not be as accurate.

TABLE 3.3 AVERAGE INFILTRATION RATES OF TWO HOUSES

	House 2 BRE (1978)			House 1 BG (1980)		
	R h^{-1}	U m/s	$\sqrt{T}$ $^{\circ}k^{\frac{1}{2}}$	R h^{-1}	U m/s	$\sqrt{T}$ $^{\circ}k^{\frac{1}{2}}$
Minimum	0.33	1.2	3.04	0.17	0.3	3.0
Maximum	1.27	8.1	4.32	0.68	5.5	4.79
Mean	0.49	3.6	3.69	0.48	1.7	3.97

R = infiltration rate U = wind speed T = Inside/Outside temp.

It can be observed from the two tables that the average infiltration rate, over a range of external conditions, is in the order of $\frac{1}{2}$ac/hr.

From the extensive measurements performed on houses 1 and 2, the dependance on external conditions have been analysed. The stack effect was found to dominate in determining the air infiltration for all wind directions except when the wind was on the front of the house. Figure 3.2 shows the relation between infiltration rate and stack effect for all wind directions except, when the wind was on the front of the houses. Figure 3.3 shows the effect of wind speed for a constant stack effect. The graphs include the data points from the 1980 BG survey, while the results from the 1978 BRE survey are represented by regression lines.

From the 1978 survey the infiltration rate was found to be highest for periods when the wind was on the front of the house. An average infiltration rate of 0.67 ac/h was calculated for an average wind speed of 4 m/s. However, most of the time the wind was either parallel to, or on the rear of, the house and for these cases the average infiltration rate was calculated to be 0.4 ac/h for an average inside/outside temperature difference of 13.6°C. The average infiltration rate for all wind directions was calculated to be 0.49 ac/h. This was considered to be low at the time compared to other modern British houses.

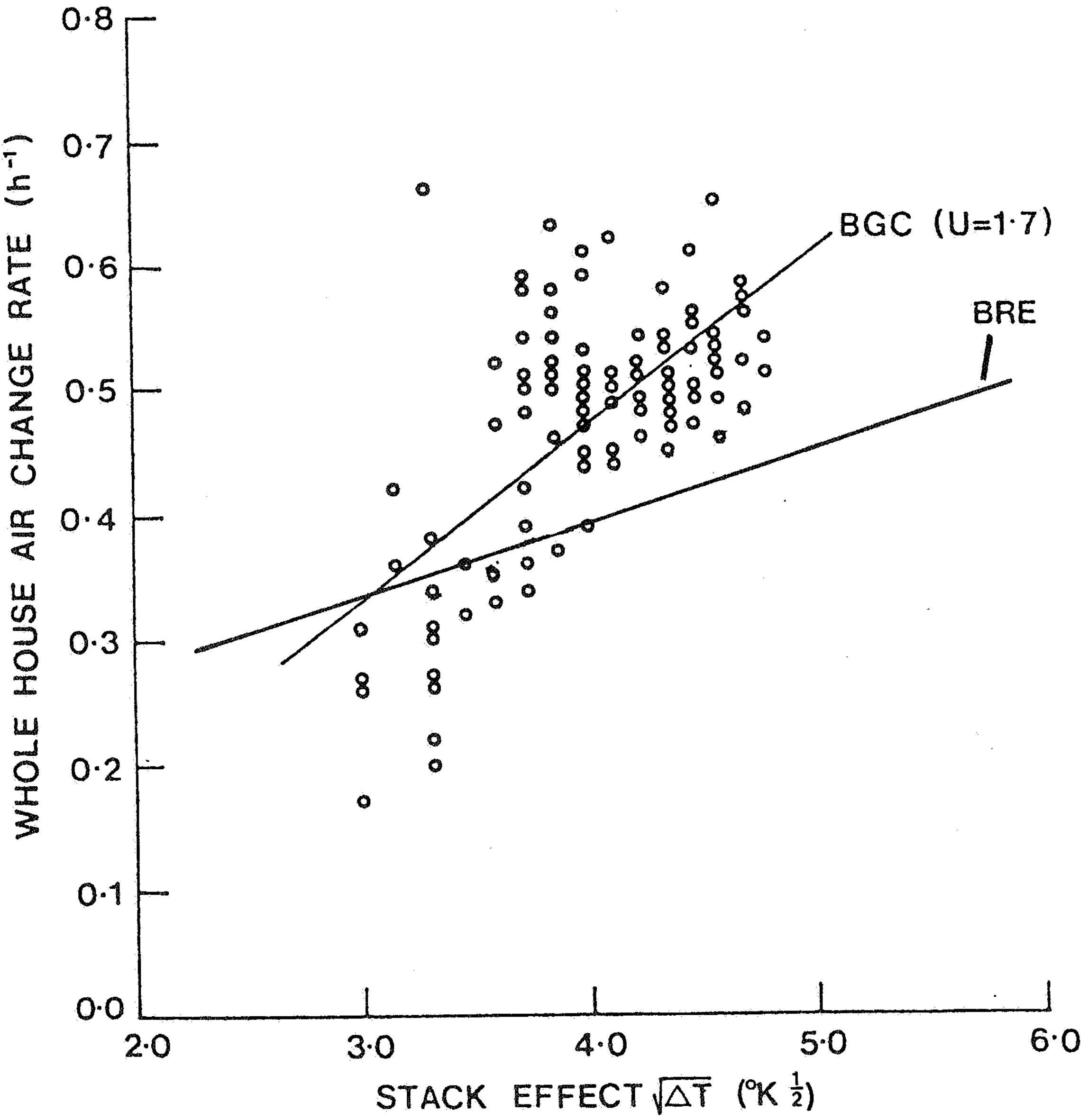


FIG. 3.2 Whole House Ventilation Dependance on Stack Effect. Wind Direction:- All but 179-229 Degrees. All Wind Speeds.

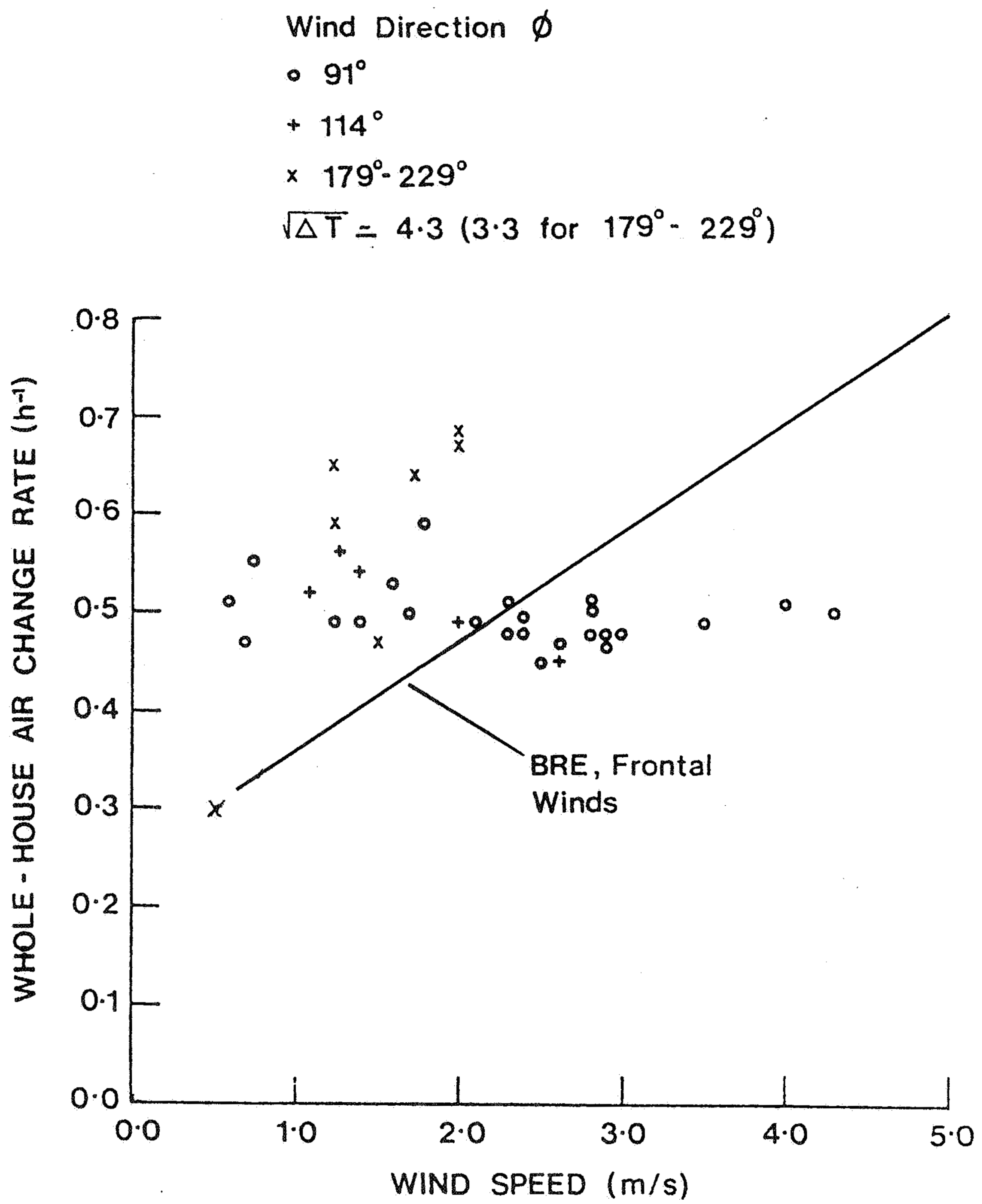


FIG. 3.3 Whole House Ventilation: Effect of Wind Speed For Constant Stack Effect.

The differences between the infiltration rates in houses 1 and 2 were not as significant as the differences in their leakage. The infiltration is dependant on the distribution of leakage with regard to the external pressure distribution. Although the major components of leakage are likely to be the same in both houses, their relationship to the pressure distribution on the building shell is likely to be different. This factor, together with the different wind conditions during each test, and bearing in mind the difference in measurement techniques was considered the major reason for the lack of correlation between the leakage and infiltration results.

Room ventilation measurements were carried out in the 1978 and 1980 surveys. The results are presented in Table 3.4.

TABLE 3.4 ROOM FLOW RATES*

Survey	Average Room Air Change Rates (internal doors closed)(House 2)								
	Living Room	Kitchen	Landing	Hall	Bath	W.C.	B1	B2	B3
BRE 1978	0.27	0.59		1.29	2.3	1.6	0.29	0.45	0.27
	Average Room Ventilation Rates (internal doors open)(House 1)								
BG 1980	0.23	0.39	0.2	2.05	2.27	0.17	0.08	0.07	0.05

The results which are again for different houses, are for two methods of measurement - the 1978 BRE survey measuring air change rates and the 1980 BG survey measuring fresh air entry. However, the methods do complement one another. The results from the 1980 survey show the hall and bathroom as having the largest fresh air entry, whole the bedrooms have very low amounts of fresh air entry. The 1978 survey shows the hall and bathroom having large air change rates with the bedroom having a reasonable air change rate. The two surveys together again identify the dominance of the stack effect in determining the ventilation characteristics, with fresh air entry by the hall and bathroom (probably via the bathroom floor where there are large service gaps) and leaving, to some extent via the bedrooms, where the air change rates are noticeably higher than the ventilation rates.

During the 1980 survey the effect of window opening, and the open/closed status of internal doors, on ventilation rate, was measured. A very limited number of measurements were carried out for various combinations of window and internal door opening patterns. The results are summarised in General terms in Table 3.5.

---

* The ventilation rate is the amount of fresh air entering the room from outside, whereas the air change rate is the total air change of the room including air entry from other rooms.

TABLE 3.5 EFFECT ON VENTILATION OF OPENING WINDOWS AND INTERNAL DOORS

COMBINATION	EFFECT ON VENTILATION RATE
Window opening	
At same level on one wall	Infiltration rate X 2
At different levels on one wall	" " X 3
On both walls	" " X 4
All internal doors closed	Ventilation rate X 0.6
Half internal doors closed	" " X 0.75

Because of the limited nature of the measurements there are obviously large uncertainties associated with the values quoted. However, they do contribute to the general understanding of the ventilation performance of the houses.

3.3 Discussion

The main results from the first series of ventilation measurements (1978 - 1980) can be summarized as follows:

It was observed that there was a marked increase in leakage rates during the first year of occupation. Since then there has been no comparable increases, and the leakage seems to have levelled out.

The average whole house infiltration rate of the houses was found to be about 0.5 ac/hr. This value is probably as low as can be achieved with traditional building techniques. However, though the whole house average infiltration rate can be considered satisfactory, in terms of satisfying ventilation requirements and being 'low' in energy terms, the individual room ventilation rates are often extremely low. The main air flow pattern has been identified as air coming in through the hall, going up the stairs, and out through the landing area, with the bathroom acting as an entry and/or exit according to outside conditions. The ventilation of the living room and bedrooms is often low with very little fresh air intake. This is an important observation, for three reasons. (i) Low infiltration rates could encourage occupants to open windows and thereby 'overventilate'. (ii) Two bedrooms in the BI houses depend on convective gains from the rest of the house as their major heat source. (iii) There have been a number of cases of serious condensation reported.

4. VENTILATION USING TRICKLE VENTILATORS

The initial series of measurements identified the need to improve the pattern of ventilation and at the same time reduce the risk of condensation. As a possible solution it was decided to test the performance of 'trickle ventilators' in three houses. Fine tune slot ventilators were fitted to the frames of all the windows in one BI house, the test house, (which was to undergo extensive tests), and in selected areas in two other BI houses where condensation was considered to be a serious problem, i.e. mould growth.

The main objective of this experiment was to improve the distribution of ventilation in the houses, increasing the level of ventilation to the bedrooms and living rooms and decreasing the levels in the Hall/landing and bathroom while maintaining the whole house ventilation rate the same. It was decided to use temporary sealing measures to produce the required decreases in ventilation. The measurement programme was carried out in February 1981.

(a) Leakage Measurements

Leakage measurements performed on the test houses before the application of sealing, measures showed an increase of about 10% in leakage compared to the 1980 survey. Sealing measures in the hall, bathroom and W.C. produced a 20% reduction in whole house leakage compared to the 1980 survey.

Measurements performed with the trickle ventilators open and then closed, revealed only a 3% difference in leakage.

Measurements of room leakage are presented in Figure 4.1, and compared with the measurements from the 1980 survey. The figure illustrates the redistribution of air leakage as a result of the installation of ventilation and sealing measures.

(b) Infiltration Measurements

The whole house infiltration rate was measured to be 0.54 ac/h for mean wind speeds of 1.63 m/s and a mean stack temperature difference of 18.6°C.

Measurements of individual room ventilation rates are given in Table 4.2 and compared to the measurements from the 1980 survey. They are averaged for vents open and closed and show the effect of the sealing measures. The overall patterns are different with decreases in the hall and bathroom rates. The bedrooms are not significantly changed although measurements of air change rate show that for bedroom 1 with vents open, although the ventilation

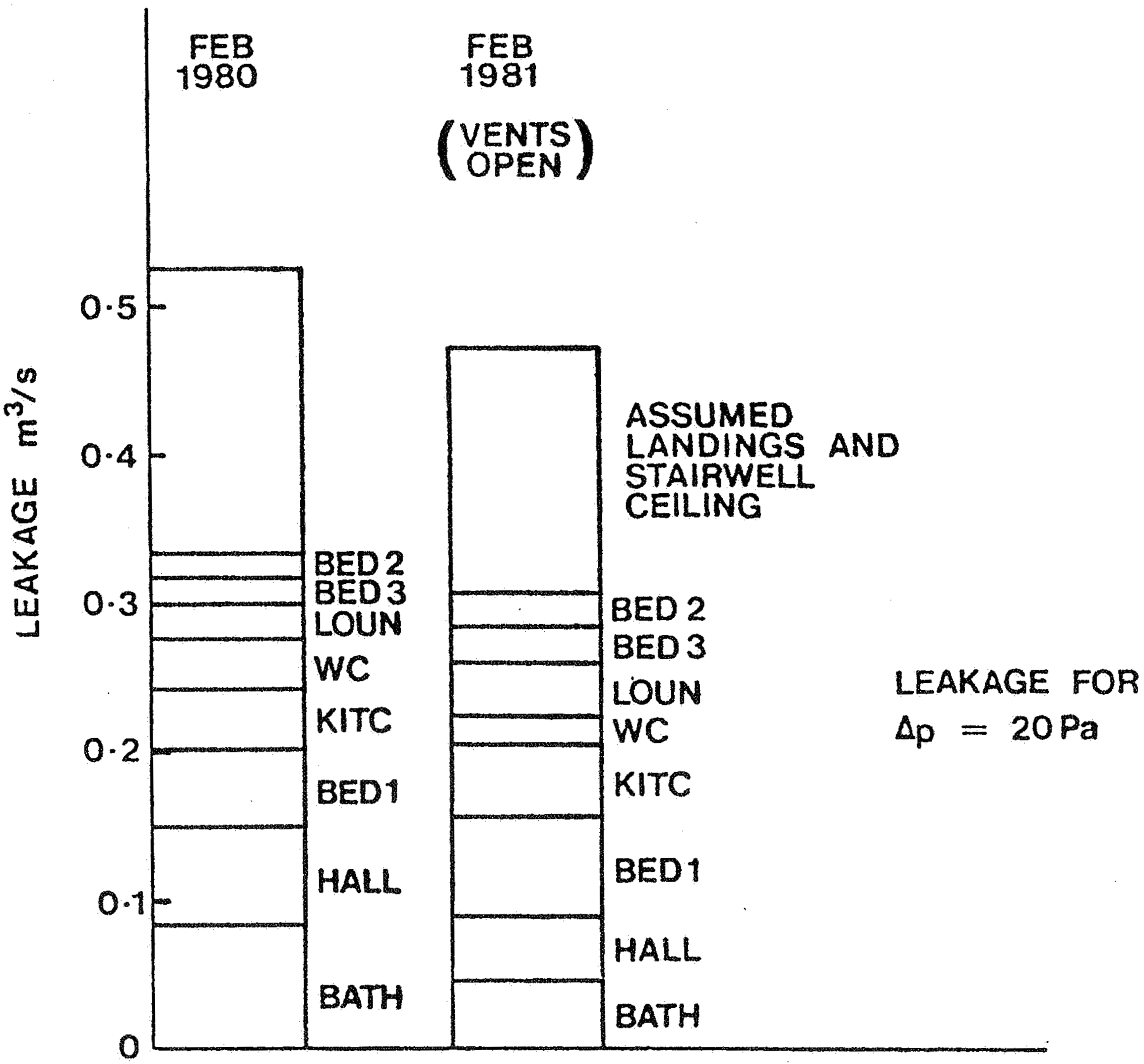


FIG. 4.1 Leakage Distributions

rate is still low the air change rate is relatively high (0.9ac/h compared with 0.29 ac/h in house 2/1978 (Table 3.4).

TABLE 4.2 ROOM VENTILATION MEASUREMENTS

	Living Room	Kitchen	Landing	Hall	Bath	W.C.	B1	B2	B3
1980	0.23	0.29	0.2	2.05	2.27	0.17	0.08	0.07	0.05
1981 (vents open & closed)	0.32	1.35	0.21	1.58	0.48	0.16	0.05	0.01	0.02
Vents Open									
Ventilation rate							0.04		
Air change rate							0.9		

(c) Discussion

To a certain extent the desired changes in the distribution of ventilation have been achieved, with the vents, when open, being able to draw air into the rooms that previously were poorly ventilated. The bedrooms now are able to achieve a higher air change rate. This improves the ventilation of these rooms and also improves the convective heat gains from downstairs.

The combination of ventilation and sealing measures have resulted in a redistribution of open area. There has been an upward shift in neutral plane with respect to the stack effect. The kitchen has now become a major source of air entry. This could cause problems in so far as the kitchen is also a source of moisture, and being in the path of a major ventilation route, the moisture would be more easily transferred to cooler spaces where condensation might occur. In hindsight, sealing the hall might have been inappropriate. The hall is rather suitable as a major air entry point. It is not normally occupied, has no moisture producing activities, and can act as a buffer zone and distribution path for the occupied rooms.

The remaining two houses which had had trickle ventilators installed showed a marked reduction in condensation levels.

5. DEMONSTRATING THE PERFORMANCE OF TRICKLE VENTILATORS

As a result of these initial tests the Abertridwr site was chosen to host a demonstration project on the performance of trickle ventilators.

Eighteen houses had trickle ventilators installed in all window frames during February 1982. There were three objectives to the experiment:

1. To assess the degree to which they were successful in reducing condensation levels.

2. To assess any energy 'penalty' due to any increase in infiltration rates.

3. To observe any change in window opening, and any energy savings resulting from reduced window opening.

Data on energy consumptions for each house was available for the before (October 1981 - February 1982) and after (March 1982 - May 1982), the installation of vents, periods. Window opening surveys were carried out during the before and after periods. Social data was collected, on use of windows/vents and occurrence of condensation, throughout the October 1981 - May 1982 period. Measurements of air leakage were performed on nine houses in July 1982.

5.1 Air Leakage

In order to assess the likely change in ventilation characteristics due to the trickle vents, air leakage measurements were performed on ten houses. The results are given in Table 4.1.

TABLE 4.1

House	Vents Closed		Vents Open	
	@ 20pa	@ 50pa	@20pa	@ 50pa
1	0.55	0.91	0.58(+5.5)	1.12(+21.2)
2	0.46	0.79	0.48(+4.3)	0.88(+11.4)
4	0.44	0.79	0.46(+4.5)	0.81(+2.5)
5	0.47	0.81	0.50(+6.3)	0.87(+7.4)
6	0.50	0.88	0.54(+8.0)	0.94(+6.8)
13	0.39	0.78	0.43(+10.3)	0.83(+6.4)
14	0.38	0.70	0.44(+15.8)	0.73(+4.3)
19	0.36	0.69	0.41(+13.9)	0.77(+11.6)
20	0.37	0.71	0.39(+5.4)	0.78(+9.9)
	Average increase		+7.1%	+9.1%

The increase in air leakage due to opening the vents is low, an average of 7.1% @20pa and 9.1% @ 50pa. The values of leakage with the vents closed compare favourably with those of previous measurement programmes (see Table 3.5).

In view of these measurements it is unlikely that the ventilation rates would be increased by more than the order of 10% by opening all vents.

5.2 Energy Consumption

Energy consumption for all 39 houses were compared for the before installation of vents and after periods. Figure 5.1 shows the monthly normalized residuals for energy consumption for one house (house 14 which has the highest measured increased air leakage). There is no evidence of any change in energy consumption due to the ventilation. There was similarly no significant change in the energy consumption identified in any of the houses, which could be attributed to the installation of the vents.

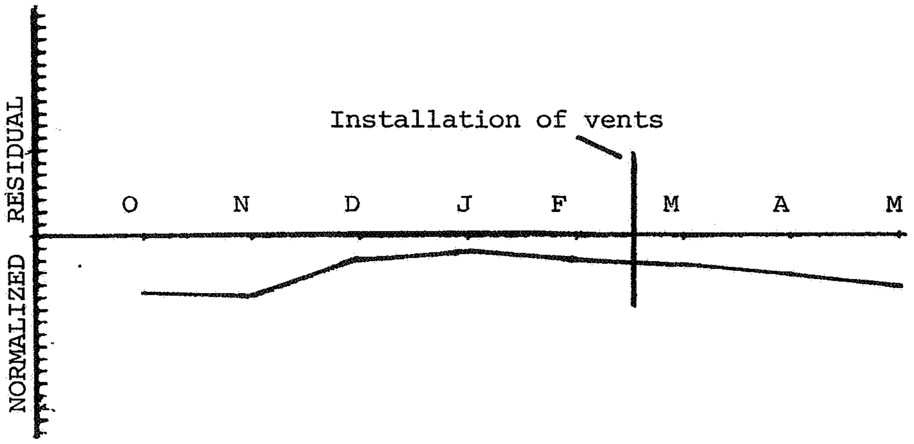


FIG. 5.1 Monthly normalized residuals of energy consumption for space heating for house 14.

5.3 Window Opening

Information on window opening was collected in two ways.

1. Occupants were interviewed about their window opening habits.

2. Window opening surveys were carried out by direct observation.

Interviews suggest that where there has been modifications to window opening because of the presence of ventilators it had mainly been during evenings and the night. Eleven out of 17 residents say they had, on occasions, reduced window opening because of the ventilators. As window opening habits are acquired through past experience one would expect change to be gradual. We found some evidence that there is a learning process as occupants, through experience, come to realise that the ventilators provide a viable alternative to window opening. This evidence is so far anecdotal. For example, residents referring to recent experience of using the ventilators as a substitute to window opening and expressing surprise at their effectiveness.

Occupants were pleased with the ventilators. They had rarely used them to 'fine tune' the ventilation. The usual pattern was to leave them permanently open. Occasional exceptions to this were the use of the living room and main bedroom (both of which are cross ventilated). The living room vents were more likely to be adjusted and more likely to be closed.

Existing ventilation habits appear to be changing, albeit slowly, with the introduction of the trickle ventilators.

The window opening surveys carried out for 4 weeks before and 4 weeks after installation have shown no clear pattern of change. However, these surveys were only carried out during the daytime. It was considered inappropriate to conduct the survey during evenings and night time as it might have been considered an infringement on the occupants privacy.

5.4 Reduction in Condensation Levels

The most positive result to come from the experiment so far is the reduction in condensation levels.

A survey was carried out on seventeen of the houses which had had trickle vents installed in order to determine the effect of trickle ventilators on condensation levels. The occupants from twelve of the houses reported that the vents had helped reduce condensation problems. Occupants from remaining five houses, reported that they had never had condensation problems to begin with.

5.5 Conclusions

(i) There is no detectable space heating energy penalty as a result of installing trickle vents. This implies that any increases in infiltration rates due to the vents (estimated at less than 10%) is small in energy terms.

(ii) There is evidence that condensation levels have been reduced.

(iii) There is no positive reduction in window opening as yet identified, however, there is some evidence of a learning process. Not surprisingly, in view of the previous findings, there is no evidence of any energy savings yet.

(iv) The 'open area' associated with trickle ventilation although large enough to alleviate condensation problems, is sufficiently small so as not to incur a significant energy penalty.

6. DESIGN METHODOLOGY

A successful methodology for the design of a naturally ventilated house would:

(a) Keep the whole house ventilation rate down to the minimum required.

(b) Ensure minimum levels appropriate to each space.

Such a system would require:

(i) Suitable air entry and exit points for each space.

(ii) Suitable interconnection between space for the necessary air flow patterns to be established.

(iii) That the combination of (i) and (ii) would provide a ventilation system which could operate effectively under the varying conditions of stack and wind.

The proposed design methodology is as follows:

Firstly, infiltration should be reduced by a generally 'tight' construction.

Secondly, open areas should be re-introduced to the external walls of the house by means of trickle ventilators.

Thirdly, the required air distribution should be achieved, according to the spatial layout, by either:

(i) using the stairwell as the main distribution duct (as at Abertridwr)

(ii) if the internal design does not allow (i), then to introduce ducting to obtain the necessary (possibly fan assisted) air distribution.

If the resulting distribution pattern includes the kitchen and/or bathroom as air entry points, extraction fans can be used to get rid of moisture at source. The risk of condensation in other spaces is alleviated by the use of trickle ventilation.

It is not envisaged that desired ventilation patterns will determine the design of the spatial layout. In energy efficient design the primary determinant of spatial layout will be the 'sensible' use of heat. Once the spatial layout has thus been determinedthe ventilation system can be designed around it in the way specified above.

Acknowledgements

Work carried out by the Building Research Establishment and by the British Gas Councils Research and Development section is gratefully acknowledged.

Figure 3.1 is taken from the BRE report entitled, 'Measurements

of air infiltration and leakage rates in well insulated houses, Abertridwr' by B.C. Webb and L.M. Parkins, which is contained in reference 3.

Figures 3.2 and 3.3 are taken from the British Gas Report entitled 'Ventilation measurements by British Gas in Abertridwr test houses' by D.K. Alexander, D.W. Etheridge and R. Gale, which is also contained in reference 3.

Figure 4.1 is taken from the British Gas Report entitled, 'Ventilation measurements in an Abertridwr house after modification' by D.W. Etheridge, which is contained in reference 4.

The views expressed in this paper are those of the authors alone and do not necessarily reflect the views of other contributors to the project.

REFERENCES

1. "Operating Efficiency of Domestic Central Heating Systems and Better Insulated Houses Programme - Abertridwr", O'Sullivan, P.E., Jones, P.J. and McGeevor, P.A., SRC Annual Report, September 1978

2. "Better Insulated Houses, Abertridwr. Monitoring of Domestic Central Heating Systems", Jessen, P.F., O'Sullivan, P.E., Jones, P.J., McGeevor, P.A. and Smith, W.A., SRC Annual Report, September, 1979

3. "Better Insulated Houses, Abertridwr. Monitoring of Domestic Central Heating Systems", O'Sullivan, P.E., Jones, P.J. and McGeevor, P.A., SRC Annual Report, October 1980

4. "Better Insulated Houses, Abertridwr. Monitoring of Domestic Central Heating Systems", O'Sullivan, P.E., Jones, P.J. and McGeevor, P.A., Final Report SRC GR/A85360, March 1982

5. "Experimental Techniques for Ventilation Research", Alexander, D.K., Etheridge, D.W. and Gale, R., AIC Conference on 'Instrumentation and Measuring Techniques', October 1980