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Passive Stack Ventilation

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PASSIVE STACK VENTILATION:
Case Studies of Reverse Flow and Humidity Control

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SYNOPSIS

The adequate ventilation of houses is essential for both the occupants and the building fabric. As air-tightness standards increase, background infiltration levels decrease and extra ventilation has to be designed into the building.

Passive stack ventilation has many advantages - particularly when employed in low cost housing schemes - but it is essential that it performs satisfactorily. This paper give the results from monitoring two passive stack ventilation schemes. One scheme was a retrofit into refurbished local authority houses in which a package of energy efficiency measures had been taken and condensation had been a problem. The other series of tests were conducted on a new installation in a Housing Association development. Nine houses were monitored each of which had at least two passive vents.

Measurements were taken over periods of three weeks in each dwelling and included; wind speed and direction, internal and external temperatures, humidity, and air velocity in the ventilation duct. The data were recorded every quarter hour.

The results show air flow rates by the passive ducts equivalent to approximately 1 room air change per hour. The air flow in the ducts was influenced by both, internal to external temperature difference and wind speed and direction. An important finding was the need to site the vents in the correct location. In those houses where the vents were installed on the roof slope facing the prevailing wind, a location not recommended in current guidance, the air flow was in the reverse direction for the majority of the time due to the design of the terminal. However, in those houses with correctly sited vent terminals of recommended design[1], reverse flow was negligible.

1. Introduction

Too little ventilation in houses often causes excessive condensation and this can lead to problems with both the maintenance of the building fabric and the health of the occupants[2]. This is a particular problem for Local Authorities who have large building stocks, which are often occupied by those least able to afford good heating and ventilation.

As part of an energy efficient renovation programme, undertaken by a Local Authority, passive stack ventilation systems were installed in a number of no-fines houses built in the 1950's. In order to avoid problems of condensation as a result of too little ventilation they incorporated passive stack ventilators in the kitchen and bathroom of each house. The systems were commercially available units and included humidity controlled dampers at the inlet of the passive stack ducts and in the replacement window frames. Mechanical ventilation systems were avoided because it had been observed that these were often over-ridden by the tenants who wished to reduce their electricity costs. Together with the passive ventilation the houses were also fitted with central heating and external insulation.

A Housing Association in Birmingham had similar reasons for specifying passive stack vents in the kitchen and bathroom of three new two-story semi-detached houses. These houses were also monitored.

Guidance has only recently been issued by BRE[3], consequently not all the systems were built to this specification.

2. Monitoring

The ventilation performance of the passive stack systems was monitored in six of the renovated houses: both the bathroom and kitchen stacks. During the tests the houses were occupied in their normal fashion. As in previous studies[4,5] the following parameters were monitored:

Weather:	Wind speed and direction
	External temperature
Stack conditions:	Air speed
	Relative humidity
	Temperature - entrance and exit
Room conditions:	Temperature
	Humidity

The temperature sensors were three wire platinum resistance thermometers. The duct air speed was measured by an omnidirectional hot wire anemometer. All the sensors were connected to a Campbell Scientific data logger. Measurements were taken every 30 seconds and averaged to quarterly hourly data points by the data logger. The monitoring period for each house was approximately three weeks and extended over the period from November 1992 to March 1993 and January 1994 to February 1994. In all 170 days of data were obtained for 15 variables.

3. Results

3.1 Air Flow Rate and Ventilation

The data were analysed to provide the mean air speed in the stack as shown in Table 1.

HOUSE	Kitchen	Kitchen	Bathroom	Bathroom	House
1	0.74	0.78	0.81	2.68	0.25
2	0.81	0.90	0.69	1.76	0.20
3	0.66	0.73	0.53	2.18	0.16
4	0.59	0.63	0.75	3.03	0.24
5	0.55	0.59	0.55	2.26	0.17
6	0.75	0.99	0.35	0.87	0.15

<u>Table 1. Mean air flows and air change rates for all data points.</u>

The air change rates given are based on either the room volume or the house volume and represent the average rate obtained over the whole of the monitoring period. The maximum duct speeds observed tended to be twice the mean value and hence the maximum air change rates achieved would be similarly greater. Whilst the maximum air flows tended to be well above the mean it was seldom that values below 0.2 m/s were recorded. Figure 1 shows a typical distribution of duct air speed. It also indicates that the duct speed has a strong dependency on wind speed. This was seen in 11 out of the 12 stacks monitored.

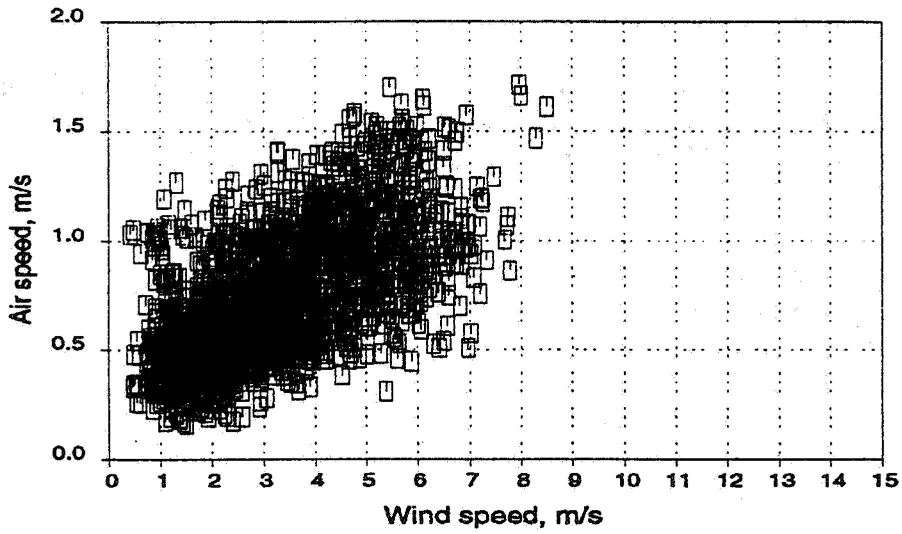

Figure 1. Stack duct air speed related to wind speed - roof pitch termination; house 1 kitchen.

3.2 Reverse Flow

On closer examination of the data it was discovered that there were large periods of time, in some of the houses, when the flow in the duct was in the reverse direction to the expected stack flow. Outside air was entering at roof level and descending down the stack, possibly distributing kitchen or bathroom air around the rest of the house. By selecting occurrences when external conditions appeared at the base of the stack these incidents of reverse flow were isolated. On analysis the reverse flow condition was found to be highly dependent on the wind direction: previous work[6] had implicated wind speed as a cause of reverse flow.

Wind Sector (45^0)	% House 1	% House 3
0-44	18	4
45-89	8	26
90-134	14	58
135-179	53	7
180-224	84	0
225-269	95	1
270-314	94	0
315-359	85	0

Table 2 shows the percentage of reverse flow for the bathroom stack for two of the houses for each 45° sector of wind direction.

Table 2. Occurrence of reverse flow related to wind direction.

These figures are illustrated in Figures 2 and 3 which also indicate that the determining factor was the location of the stack exit, or roof terminal.

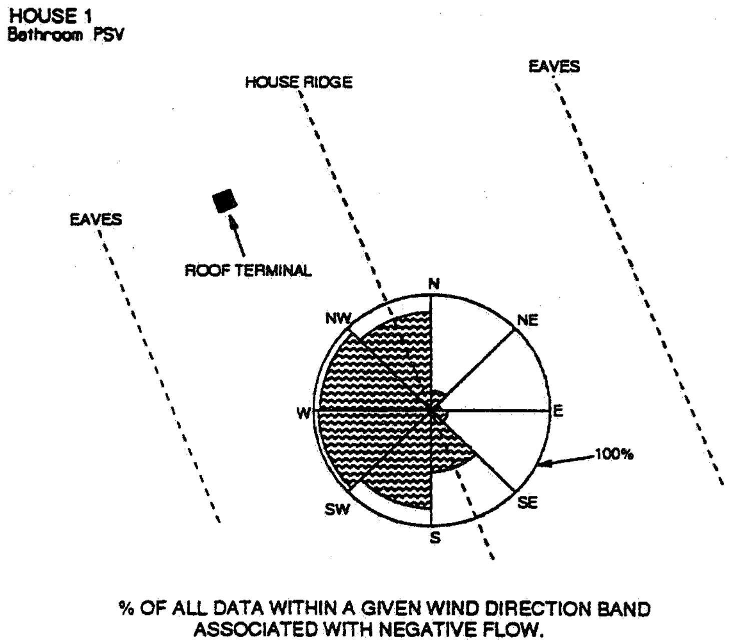

Figure 2. Distribution of incidence of reverse flow against wind direction House 1 - bathroom.

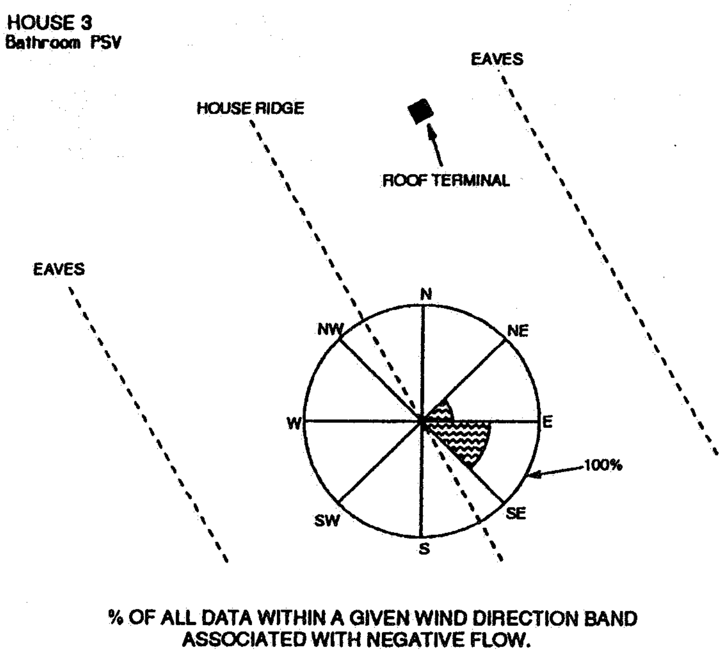

Figure 3. Distribution of incidence of reverse flow against wind direction House 3 - bathroom.

The figures clearly show how the roof terminal installed on the roof pitch facing the prevailing south-west wind experienced considerable periods of reverse flow. In the house in which the terminal was on the leeward side reverse flow was less frequent and only occurred when the wind was in the appropriate quadrant. This location is contrary to recent guidance, developed as a result of monitoring studies such as these.

3.3 Humidity Control

To allow for an investigation of the humidity control, in two of the houses the monitoring had been carried out without the humidity controlled dampers at the base of the stack.

The humidities measured were within the normal range expected of occupied houses. Mean values were between 40% and 60% RH, with standard deviations of around 6% RH. The maximum values were typically between 60 - 90% RH.

Figure 4 shows the minimum, mean and maximum relative humidities recorded in the kitchen and bathroom of each house.

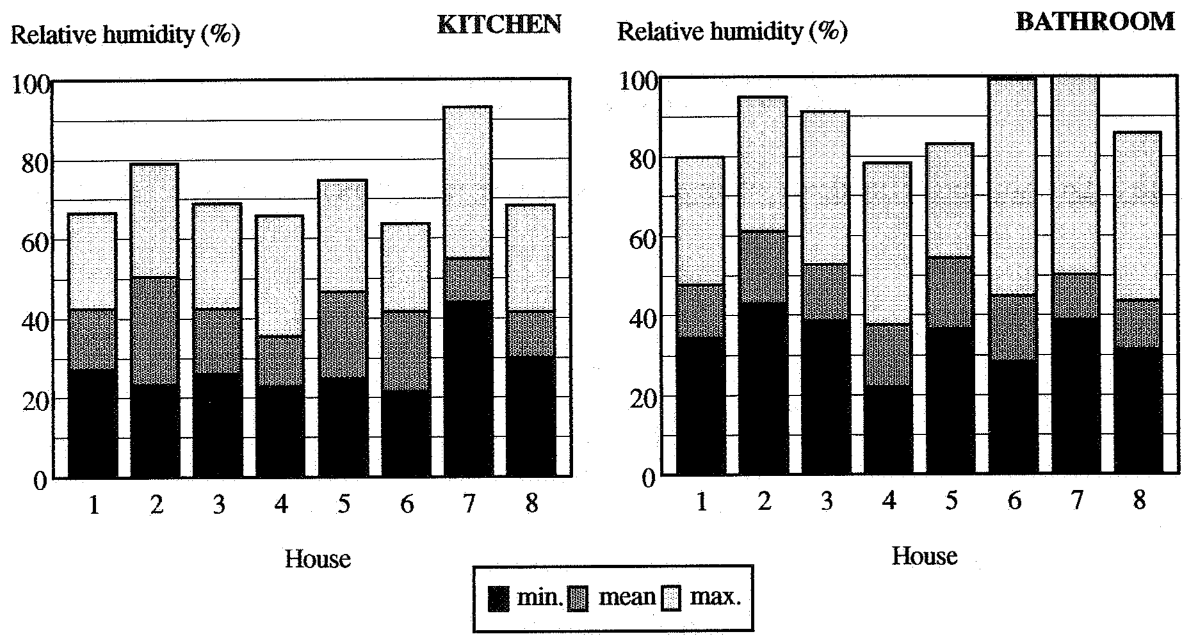

Figure 4. RH levels in the kitchen and bathroom of each house

Visual scanning of the plotted data did not reveal any substantial relationship between duct air speed and humidity in the room it was serving. In order to investigate the data more thoroughly it was decided to try to relate an increase in duct air speed to an increase in the humidity in the room in the previous 15 minute period. In a house with humidity control this should show an increase in the humidity causing the control dampers to open and thereby increase the air flow rate provided other variables affecting the flow rate remain constant and the humidity control device responds fully within the measurement time..

In the uncontrolled house this would not be expected, although it is appreciated that a small increase in speed may be seen because of the reduced density of the moister air. When plotted out the results were as figures 5 and 6.

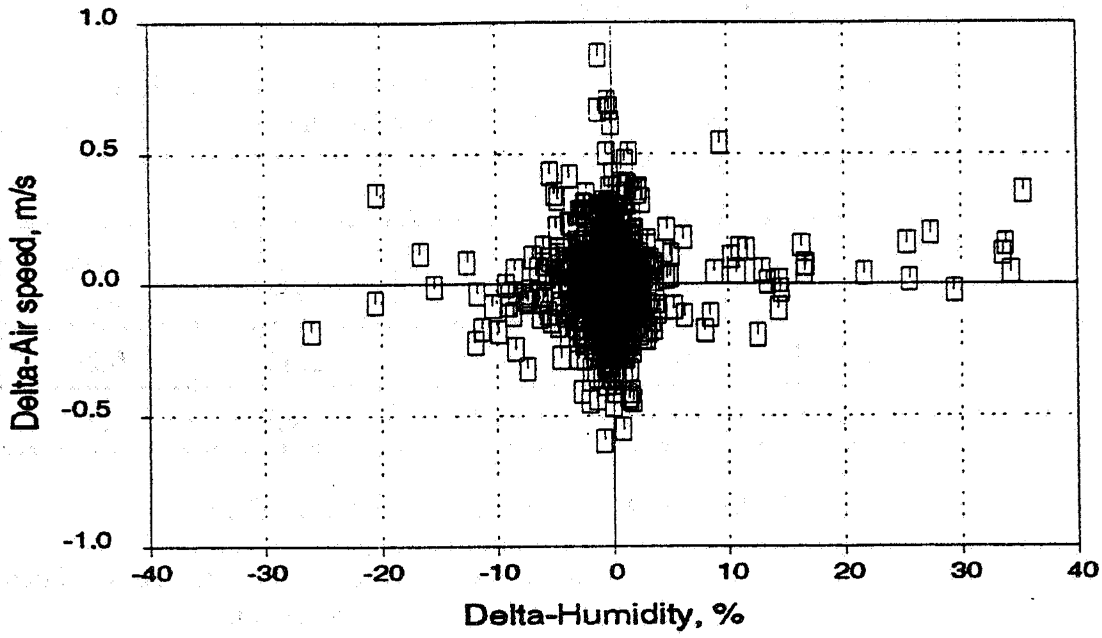

Figure 5. Change in duct air speed against change in humidity with humidity control.

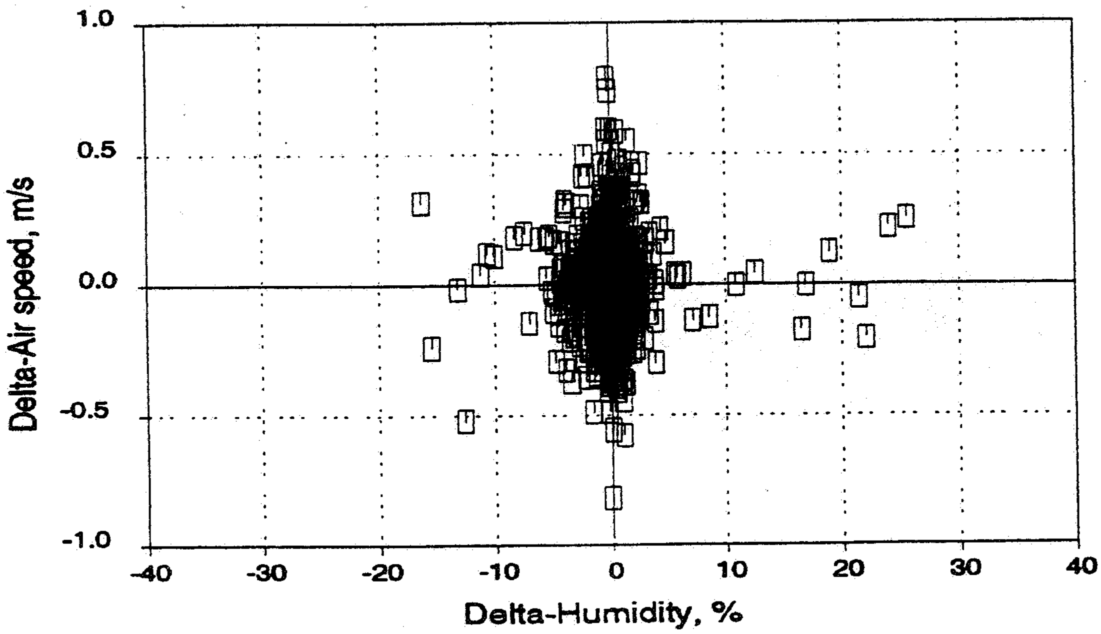

Figure 6. Change in duct air speed against change in humidity with no humidity control.

As can be seen from figures 5 and 6 there is no discernable difference in the air speed in either case, however, the time constant of the humidity device may be of the same order as the averaging time for the humidity and the small changes in humidity are likely to produce small changes in the flow of the same order as random changes produced by the fluctuations in wind speed and temperature.

3.4 Birmingham Housing Association Houses

These houses had the vents terminated correctly[3] at the ridge and this is reflected in the absence of reverse flow. Ridge termination also made the stacks taller, thereby enhancing buoyancy induced air movement. The mean air flows are shown in Table 3.

House	Kitchen m/s	Kitchen ach	Bathroom m/s	Bathroom ach	House ach
1S	1.16	1.72	0.86	2.33	0.26
2S	0.99	1.47	0.61	1.65	0.20

Table 3. Mean air flows and air changes per hour in the Birmingham houses.

Figure 7 shows that the Birmingham houses were less sensitive to wind speed than the Local Authority installations: at wind speeds of up to 4 m/s there was no effect.

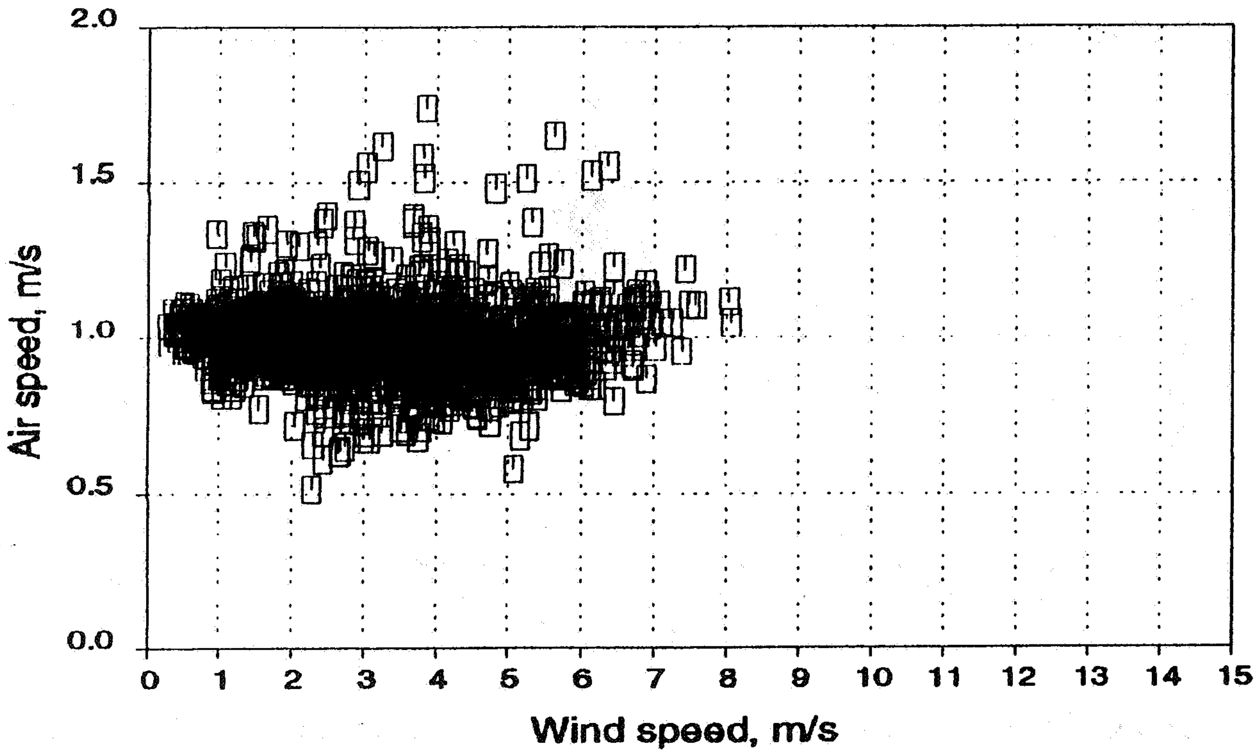

Figure 7. Stack duct air speed related to wind speed - ridge termination.

4. Conclusions

The installation of passive stack ventilation systems can be a useful way to provide good levels of back-ground ventilation in houses. However, good practice must always be observed. Ridge termination of the stacks is recommended and this study shows the degree to which poor performance results from poor location.

However, average humidity levels were below 60% RH in all except one house and below 70% in all houses. With the relatively small changes in RH (generally less than 5%), there seemed to be no relationship between changes in RH and changes in stack velocity but it may be that the changes in relative humidity produce a change in flow indistinguishable from random fluctuations due to temperature and wind variations. In any event it would seem that the levels of ventilation achieved would not be excessive even without the humidity control.

The results from the houses with ridge situated termination are very encouraging with good levels of reliable, and not excessive, ventilation.

ACKNOWLEDGEMENTS

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