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TWO-DIRECTIONAL AIR MOVEMENTS IN STAIRWELLS

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Abstract

The predominant route for air movements between the floors of two-storey dwellings is via the stairwell. Such air movements are of significance in the assessment of building performance: for instance, it is possible that moisture could be transferred from ground floor areas to rooms on the first floor, resulting in an increase in condensation risk in such rooms. Several domestic heating schemes have been designed such that heating appliances are provided on the ground floor only; the upper floor relying on convective airflows for heating. If the ground floor to first floor airflow induce by such a system is too small, then the upstairs room will not attain the desired temperature, which in turn could lead to condensation problems, quite apart from the issue of occupant discomfort.

This paper summarises two case studies of air movement measurements performed by means of the UMIST PCS system, and analyses the data in terms of moisture migration and heat transfer.

Introduction

Condensation in dwellings has proved to be one of the biggest technical problems confronting the building professions during the 1980s. The three principle causes of condensation can be reasonably said to be inadequate heating, inadequate ventilation and occupant behaviour, and much research in the field has been concerned with the influence of these variables. Ventilation research in relation to condensation has generally been confined to measurements of whole house ventilation rates: air movements within dwellings have received comparatively little attention, mostly, it suspected by the authors, as a result of a lack of widespread access to suitable interzonal airflow measurement apparatus. Air movement within a building envelope can be a significant factor in the occurrence of condensation risk: for instance, it could be envisaged that water vapour could be transferred by air movement from areas of high moisture production within a dwelling (such as kitchens and bathrooms) to other rooms if insufficient consideration is given to building layout and distribution of ventilation.

This paper briefly describes two studies of airflows between the two floors of domestic properties. The first study centres upon an assessment of the efficiency of a partial heating scheme within a local authority property, in terms of the provision of sufficient heating to the first floor. The second study is concerned with the influence of a kitchen extract fan upon upstairs/downstairs airflows.

Experimental

i) Partially-heated house.

The test house is shown in figure 1. It is a local authority-owned house, and is a mid-terraced property. The design U-values of the walls and roof (0.27 and 0.35 $W/m^2/degC$ respectively) are significantly lower than those laid down by the Building Regulations in force at the time of construction (1984). All windows are single glazed. The house is heated by two balanced-flue gas heaters. The first is located in the lounge, and is rated at 0.76 to 2.35 kW output. The second heater is located in the hall. It is fitted with a heat exchanger for space heating, and is rated at 0.83 to 2.5 kW output. In order to supply background heating to the ground floor stores and WC, permanent grilles are provided give free passage of air from the lounge to the WC via the two stores. A wall fan, switched with room lighting, is installed in the WC so as to ensure a background level of air movement from the lounge to these spaces. The purpose of the house design is to heat the first floor by means of natural convection. To encourage air movement on the first floor, fanlights are positioned above all first floor doors, and, in addition, gaps have been deliberately left under the doors themselves. A fan pressurization test of the property revealed an air leakage rate of $1787m^3/hr$ at 50 Pascals positive pressure difference, which represents an air change rate of approximately 9.7ach.

During the tracer gas study, the following parameters were measured and recorded:

a) ventilation rates on the ground floor and first floor;

b) two-directional air movements between the two floors;

c) dry and wet bulb temperatures on both floors;

d) external dry and wet bulb temperatures;

e) wind speed and wind direction at a height of 10 metres.

ii) Low energy house

In this study, the test house is a three-bedroomed, end-terraced local authority property of low energy design: ground and first floor plans are shown in figure 2. The house was built in the early 1980s, and is of brick and block construction with a filled cavity. The design U-values of walls and roof are 0.24 and 0.27 $W/m^2/degC$ respectively .The windows are double glazed. The house is heated by means of a solid fuel heater, which supplies ducted warm air to both floors. Careful consideration was given to the issues of air leakage and ventilation provision at the design stage. The design ventilation rate is set at 1.0ach: this has been achieved by paying careful attention to the quality of joints in the construction, by the use of draught stripping, and by the provision of draught lobbies. The kitchen is fitted with extract fan, whilst all windows are fitted with window head trickle ventilators. For this particular study, the trickle ventilators an internal doors were left open.

The parameters measured during the tracer gas study were to all intents and purposes the same as those measured during the partially heated house study.

iii) Details of tracer gas technique

Ventilation rates and inter-zonal air movement measurements were performed using the PCS equipment developed at UMIST.[1] Briefly, the equipment consists of an Analytical Instruments Model 505 portable electron capture gas chromatograph, modified for parallel column operation. The purpose of the modification is to increase the rate of data acquisition by utilising the "dead time" associated with the passage of air/tracer gas samples through a chromatographic separation columns.

In both studies, two tracer gases were used, namely Freon 12 and Freon 114. Prior to tracer gas injection, the two floors of the test house in question were isolated by means of a PVC sheet and adhesive tape. The tracer gases were injected, (Freon 12 into the ground floor, Freon 114 into the first floor: good mixing was achieved by means of oscillating fans. At the commencement of each test, the PVC sheet was removed.

Results and Discussion

i) Partial heating study.

The results are given in table 1. For this house, whole house ventilation rates, taken as the mean of the ground floor and first floor ventilation rates, varied between 0.38-0.91 air changes per hour for a range of windspeeds between 1.0 and 5.5 m/s. Variation in wind direction during the test period was very limited, but despite this, it is apparent that whole house ventilation rates are rather sensitive to changes in wind direction. As might reasonably be expected, wind directions perpendicular to the ridge axis are associated with the highest whole house ventilation rates for a given windspeed.

Air movements between ground and first floor with the heaters on lie in the range of 100 to 250 m^3/hr, whilst air movements in the opposite direction lie in the range of 60 to $100m^3/hr$, airflows lie in the range 130 to 178m^3/hr: airflows in the opposite direction are of a similar order of magnitude. When the kitchen fan is switched on, however, the ground floor to first floor airflows are reduced to the range 10-30m^3/hr. At windspeeds less than 2m/s, the use of the kitchen fan does not appear to have a pronounced effect upon first floor to ground floor airflows: above this value, however, increasing windspeed has the effect of reducing the airflow from first floor to ground floor. This is due to the increased cross-flow ventilation on the first floor.

The value of extract fans in the removal of water vapour at or close to the area of production is well established. Quite apart from reducing the vapour pressure in the zone in which the fan is located, the concomitant reduction in airflow to the first floor is of the order of 85%, which would result in a significant reduction in the amount of water vapour being allowed to migrate to rooms on the first floor such as bedrooms which are susceptible to condensation problems. It should be mentioned in passing that there is another benefit to the use of the ground floor extract fan namely that airflow (and hence migration of water vapour) into the roofspace is also significantly reduced.[3]

CONCLUSIONS

The two studies briefly described in this paper demonstrate the usefulness of multiple tracer gas techniques in the measurement of airflows between two floors of a dwelling. It should be acknowledged, however, that the division of a typical two floor house in two zones represents an approach to the measurement of airflows which may in many cases not be sufficiently sophisticated to yield data with sufficient detail. In such circumstances, the degree of subdivision, and hence the number of tracer gases used, should be increased.

REFERENCES

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Final report to BRECSU, 1987.

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Test No.	Temp(Up) db °C	Temp(Up) wb °C	Temp(Dn) db °C	Temp(Dn) wb °C	Temp(out) db °C	Temp(out) wb °C	Downstairs Vent Rate (ACH)	Upstairs Vent Rate (ACH)	Whole House Vent Rate (ACH)	Airflow Dn to Up (m^3/hr)	Airflow Up to Dn (m^3/hr)	Wind Speed (m/s)	Wind Direction	Comments
1	19	15	18	14	12	11	0.84	0.74	0.79	140	75	4	NW	All windows shut Htg on
2	19.5	15	19	15	12	10	0.80	0.98	0.89	130	100	3.5	W	W facing bed. window open
3	"	"	"	"	"	"	0.55	0.42	0.49	100	100	1	NW	All windows shut heating off
4	20	16	20	16	12	10	1.25	0.55	0.90	120	60	5	NW	-Ditto-
5	12	8	12	8	14	11	0.4	0.4	0.4	30	10	<1	SW	-Ditto- heating off
6	14	9	15	10	10	8	0.62	0.38	0.5	125	110	1	NW	-Ditto- heating on
7	15	10	17	12	10	8	0.71	0.51	0.61	100	95	2	NW	-Ditto-
8	17	10	17	10	11	9	1.00	0.75	0.88	150	100	4	NW	-Ditto-
9	19	16	21	18	10	8	0.48	0.32	0.40	95	70	1.5	W	-Ditto-
10	19	16	21	18	11	8	0.55	0.29	0.42	100	100	2	NW	-Ditto-
11	16	10	18	12	8	6	0.78	0.52	0.65	55	100	3	NW	Gr.floor window open,htg on
12	16	10	18	12	8	6	0.85	0.45	0.65	40	90	2.5	W	-Ditto-
13	17	10	16	10	8	6	0.99	0.58	0.79	70	115	5	NW	-Ditto-
14	18	11	14	9	8	6	0.65	0.49	0.57	80	100	4	W	-Ditto-
15	19	15	19	15	9	7	0.55	1.00	0.78	110	49	3.5	NW	1st floor window open
16	17	13	19	15	9	7	0.45	1.25	0.85	120	55	5	W	-Ditto-
17	16	12	19	15	9	7	0.81	1.01	0.91	100	50	5.5	NW	-Ditto-
18	14	10	20	15	10	6	1.01	0.75	0.88	50	40	4	W	Gr & 1st floor windows open
19	14	10	17	13	10	6	0.86	0.78	0.82	78	81	3	NW	-Ditto-
20	12	9	16	13	9	7	0.65	0.65	0.65	85	58	4	NW	-Ditto-
21	12	9	16	13	9	7	0.72	0.49	0.61	120	80	2.5	W	-Ditto-
22	21	17	21	17	9	9	0.45	0.31	0.38	150	150	1	NW	All doors shut
23	22	17	22	17	10	8	0.51	0.29	0.40	125	110	2	NW	-Ditto-
24	10	7	10	7	12	8	0.65	0.45	0.55	100	100	1.5	W	-Ditto-
25	10	7	11	7	13	7	0.71	0.58	0.65	85	75	2.5	SW	-Ditto-

Table 1.

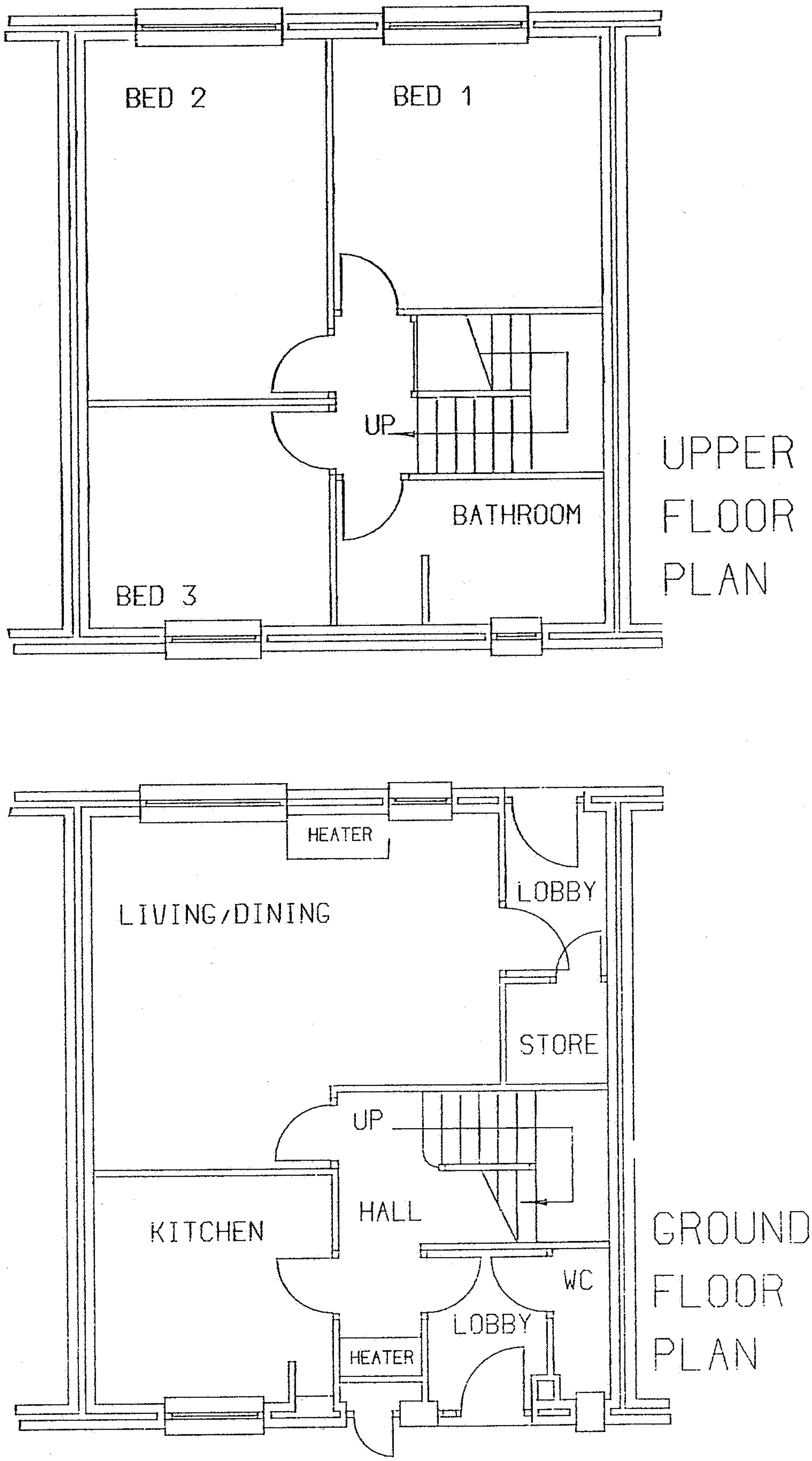
BED 2
BED 1
UP
BATHROOM
BED 3
UPPER
FLOOR
PLAN
HEATER
LOBBY
LIVING/DINING
STORE
UP
HALL
KITCHEN
WC
LOBBY
HEATER
GROUND
FLOOR
PLAN

Figure 1.

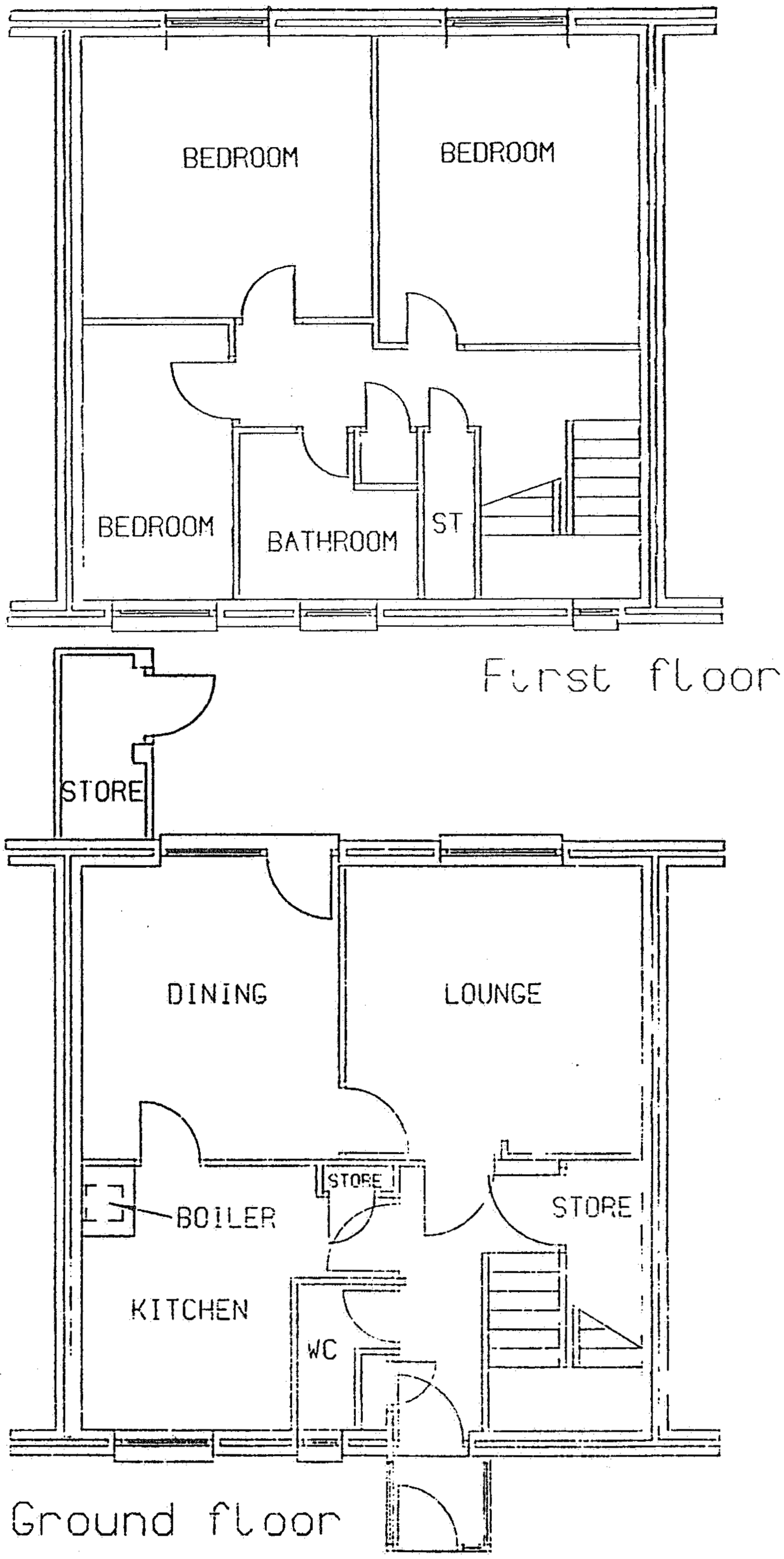
BEDROOM
BEDROOM
BEDROOM
BATHROOM
ST
First floor
STORE
DINING
LOUNGE
STORE
BOILER
STORE
KITCHEN
WC
Ground floor

Figure 2.

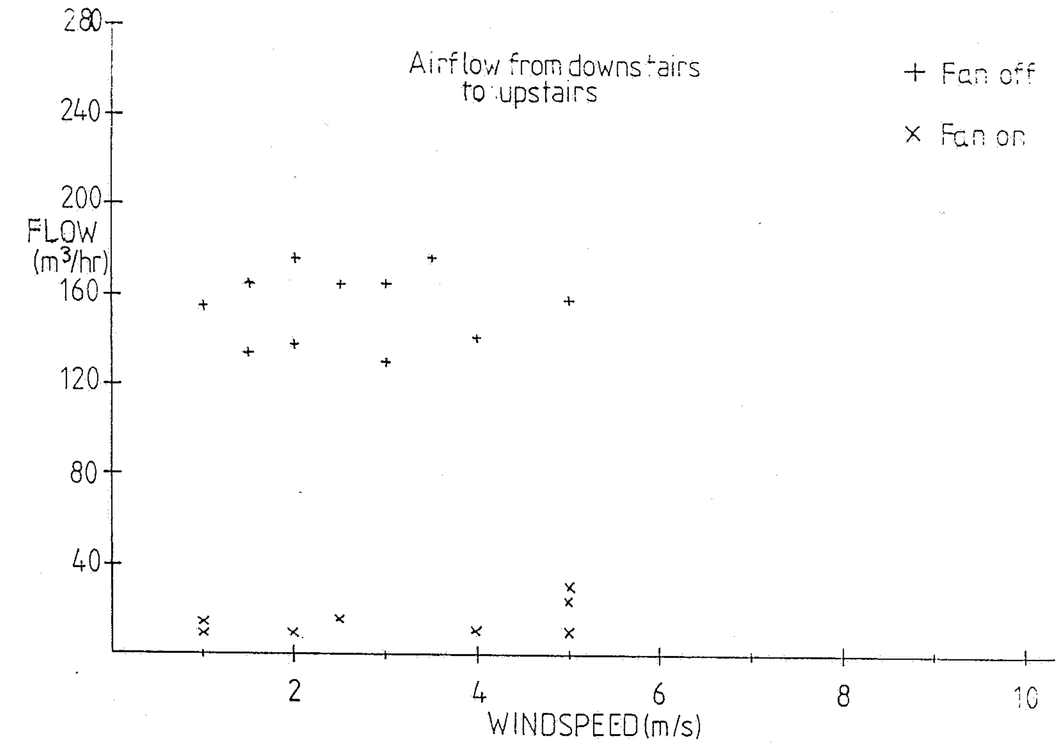

Figure 3.

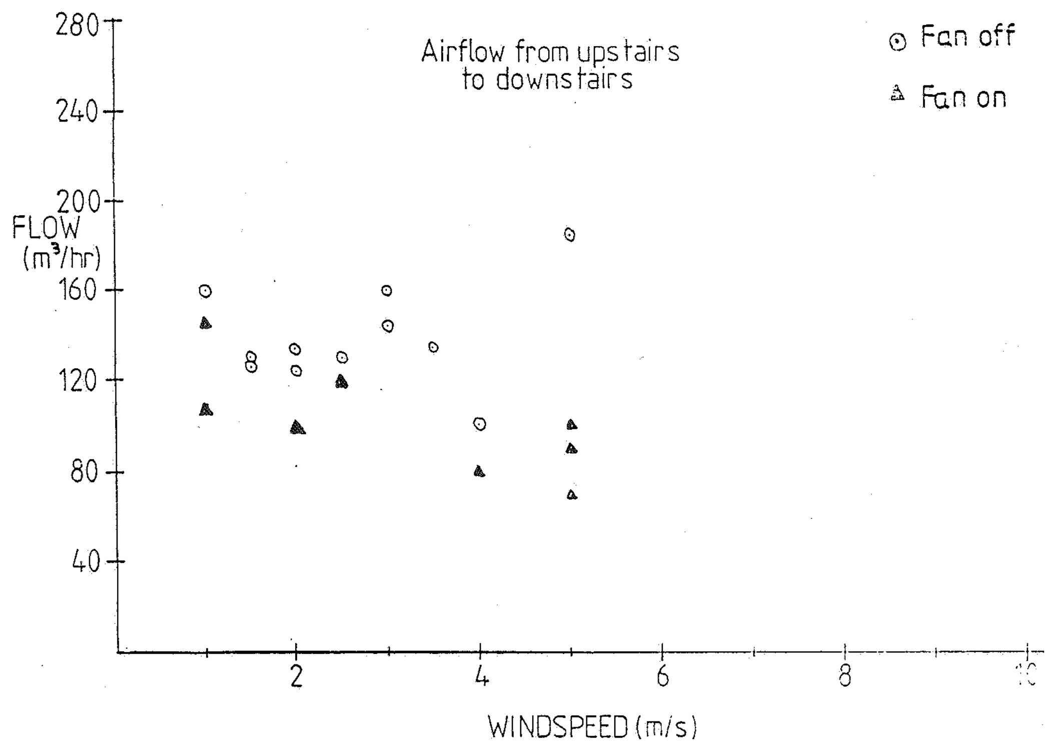

Figure 4.