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AIR FLOW THROUGH AND WITHIN MASONRY WALLS

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SUMMARY

The thermal performance of a house wall may be worse than expected if air flow takes place through or within the wall structure.

The gable wall of one of the test houses is of brick/foam-filled cavity/block/air gap/plasterboard construction typical of many modern houses.

Air flow through the wall was investigated by sealing a metal box onto the outer brickwork and measuring the relationship between air flow and applied pressure. Measurable air flow was achieved at relatively high applied pressures but at ordinary wind pressures the effect on ventilation rate and thermal performance is negligible.

Smoke tests showed that joints between dissimilar wall components are a far more significant air flow path.

Air flow behind the dry lining was detected using smoke and tracer gas methods. Inadequate sealing of the dry lining resulted in outside air penetrating the building envelope and extracting heat from the house without contributing to the ventilation.

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CONTENTS

		Page No.
1.	INTRODUCTION	1
2.	APPARATUS FOR MEASUREMENT OF WALL PERMEABILITY	1
	2.1 Calibration	1
3.	EXTERNAL SMOKE TESTS	2
4.	PRESSURE TESTS	3
5.	AIR FLOW BEHIND PLASTERBOARD DRY LINING	4
	5.1 Internal smoke tests	4
	5.2 Tracer tests	5
	5.3 Heat loss	5
6.	CONCLUSIONS	6
7.	REFERENCES	6

FIGURES 1-8

1. INTRODUCTION

Brick or masonry walls are porous and permeable to air. Air flow through external walls under the influence of wind or temperature-induced pressure differences could affect the thermal performance of houses. Accordingly, a simple experiment was devised to assess the likely magnitude of this effect.

A related problem is the flow of air, mainly by convection, in cavities within walls as this will also influence house heat loss. The flow behind plasterboard dry lining was therefore also investigated.

2. APPARATUS FOR MEASUREMENT OF WALL PERMEABILITY

The gable wall of ECRC test house No. 16 was chosen for these measurements. The wall construction is brick, foam-filled cavity-block-air gap-plasterboard. The front and back walls of this house are wood frame panels with boarded and tile-hung exteriors.

The general arrangement of the apparatus is shown in Figure 1. A shallow metal box of area 0.5 metre^2 was clamped and sealed against the wall adjacent to the dinette. The method of sealing is indicated in Figure 1, and at the seal the depressions between the bricks were first filled with putty up to the level of the brick surface. A metal frame 100mm wide was then placed on the wall with 10mm thick PVC foam sealing strip between it and the wall. The box was then clamped against this frame with a further strip of PVC foam. An angle iron clamp held the whole assembly tight against the wall with four 'Rawlbolts', as in Figure 2.

An industrial vacuum cleaner controlled through a 'Variac' supplied air through a 2m x 100mm diameter PVC tube with a vane anemometer at its mid-point to measure the air flow. The pressure difference between the inside of the box and the outside was measured with a liquid maonometer. Additional clamping pieces of wood were also used as shown in Figure 3.

2.1 Calibration

The apparatus was calibrated for flow by clamping a sheet of rigid plastic across the open side of the box (i.e. in place of the wall) and then drilling 8mm holes in the plastic sheet one at a time. This produced the family of flow versus pressure curves shown in Figure 4. The air flow was found to be proportional to $\Delta p^{0.5}$ and so the standard orifice formula applies:

$$Q = 0.827\ A\ \Delta p^{0.5}$$

where Q = air flow in m^3s^{-1}

A = orifice area in m^2

Δp = pressure difference in Pa

The relationship between vane anemometer reading and number of holes is shown in Table 1. It is seen that after 4 holes had been drilled the vane anemometer read 0.36 m/s per hole independent of the number of holes. This suggests that the background leakage is negligible under those conditions. Applying the above formula for orifice flow and dividing it by the air speed reading gives an effective area for the vane anemometer of 0.0063 metre^2.

TABLE 1 FLOW CALIBRATION DATA

No. of 8mm holes	Vane anemometer reading at Δp = 3000 Pa	
	m/s	m/s per hole
1	0.41	0.41
2	0.77	0.39
3	1.11	0.37
4	1.45	0.36
5	1.81	0.36
6	2.14	0.36

The same data also provide an effective leakage area calibration as shown in Figure 4. This however is only approximate because the flow-pressure relationship for brickwork does not follow a $\Delta p^{0.5}$ dependence.

3. EXTERNAL SMOKE TESTS

Smoke introduced into the inlet of the vacuum cleaner was used to check the apparatus for leaks and also to assess qualitatively the leakage of the wall.

It was found that smoke could be forced right through the wall, emerging in the house (in the dinette, loft and airing cupboard) and also at the outside joint between the rear frame wall and the brick wall.

The applied pressure was 3000 Pa which is much greater than typical wind pressures of up to a few tens of Pa.

4. PRESSURE TESTS

Sealing of the box to the brickwork was difficult and so the background leakage of the apparatus in situ was first measured by sealing the brickwork with a sheet of heavy duty polythene sealed around its perimeter with mastic.

The polythene was then removed and leakage of the brick wall was measured, then repeated with the vertical joints sealed with mastic, and finally with all the mortar joints sealed with mastic as in Figure 5.

The results are given in Figure 6. Results were nearly identical whether sucking or blowing which indicates that the clamping arrangement was effective.

The total leakage measured is roughly equivalent to a hole of area $0.00015m^2$ and subtracting the background leakage of $0.00005m^2$ the effective leakage area of the brick wall is found to be $0.0002m^2$ per m^2 (since the area under test is $0.5m^2$).

The air flow through the wall was found to follow a relationship:

$$Q = 0.133 \ \Delta p^{0.67} \qquad m^3/h \text{ per } m^2 \text{ of wall}$$

Taking 200 Pa as a standard pressure for comparison with other measurements a leakage of $4.6m^3h^{-1}\ m^{-2}$ is obtained which is similar to the values quoted by Thorogood (1). If it is assumed that this relationship is valid at typical wind pressures an estimate of the wind induced air flow through a wall of area $30m^2$ is possible, Table 2. House volume is $200m^3$.

TABLE 2 WIND INDUCED FLOW THROUGH BRICK CAVITY WALL

Wind speed	Velocity pressure	Predicted flow	Flow through a $30m^2$ wall	
m/2	Pa	$m^3h^{-1}m^{-2}$	m^3/h	ach
2	2.4	0.24	7	0.04
4	9.6	0.61	18	0.09
10	60	2.01	62	0.3

The associated heat loss will however not be as great as for conventional ventilation because of heat exchange between the wall and the air flowing through it. In any case the contribution to the ventilation would be significant only at very high wind speeds.

From Figure 6 the leakage can be apportioned as in Table 3.

TABLE 3 RELATIVE LEAKINESS OF BRICKS AND MORTAR

Component	% of leakage	% of area	relative leakiness
Vertical joints	43	4	42
Horizontal joints	36	13	11
Bricks	21	83	1

It is seen that the mortar joints, especially the vertical ones, are responsible for letting most of the air through the wall.

5. AIR FLOW BEHIND PLASTERBOARD DRY LINING

The brick/block walls of ECRC House 16 are drylined. Thermovision pictures and exploratory holes show that the plasterboard rests on vertical ribbons and occasional dabs of plaster with a gap between the blockwork and the plasterboard of 3mm to 15mm.

Ispection in the loft and behind the bedroom skirting showed that the cavity behind the dry-lining is open at the top. At floor level behind the skirting, wet plaster had been used but gaps existed so that effectively there was a continuous path behind the plasterboard from loft to basement.

5.1 Internal smoke tests

Smoke sources placed in the gap behind perspex windows set into the plasterboard enabled the air flow to be observed. The outside temperature was 2^{o}C, inside temperature 18^{o}C, wind 250^{o} 3 m/s (house faces 135^{o}). The observed air flow was up upstairs and down downstairs as shown in Figure 7 for the gable wall. The air movement was upwards in the party wall.

Opening and closing the front door 'pumped' the air in the gap. The flow was up, upstairs and down, downstairs, as the door was opened.

With a strong wind onto the front of the house (110^{o}, 8-10 m/s) smoke injected behind the dry-lining in the dining room near the corner of the brick and frame walls rapidly emerged outside be tween the boards of the rear wall and the brickwork. The same effect was noted upstairs in the back bedroom.

A large amount of smoke was then injected into the space between the downstairs ceiling and upstairs floor via the airing cupboard. This smoke emerged along the brick/board and brick/tile joints on the outside of the house and also from between the weatherboards and under the tiles.

5.2 Tracer tests

Since injecting or sampling behind the plasterboard influenced the flow being measured, tracer gas was used only to detect flow between loft and basement.

At the party wall, gas released just under the ground floor was detected in the loft after 60 seconds, the vertical separation of source and detector being 5 metres. No downward motion of tracer gas was detected here.

At the gable wall no reproducible flow between loft and basement was found in either direction. However, tracer gas injected above the downstairs ceiling indicated a definite downward flow downstairs (2.5 metres in 90 seconds) and a rather weak upward flow deflected downwind of the injection point. The wind was obliquely on the front of the house 4 m/s, 110°.

These measurements confirmed the smoke tests and indicate that the air speed behind the plasterboard is 0.08 m/s in the party wall and 0.03 m/s in the gable wall.

5.3 Heat loss

Temperature measurements showed that when it was 2°C outside and 18°C inside the air temperature behind the dry-lining was about 16°C and the air in the crawl space under the ground floor, about 8°C. Assuming a gap behind the dry-lining of 10mm, a wall length of 7 metres and an air speed of 0.08 m/s the associated rate of heat loss up the party wall is 50 watts.

If it is assumed that the flow up and down the gable wall at 0.03 m/s is replenished by outside air via the interfloor space the associated rate of heat loss is 70 watts but this would not be detected at the wall because the incoming cold air would be heated up in the interfloor space. Under these temperature conditions the rate of normal heat loss by conduction through the wall is 240 watts assuming a U-value of 0.5 $W\ m^{-2}\ K^{-1}$ and an area of 30 $metre^2$.

6. CONCLUSIONS

Brick walls are permeable but most of the permeability is associated with the mortar joints.

Under average wind pressures the effect on ventilation and heat loss can be neglected.

Plasterboard dry-lining if not sealed effectively in both horizontal and vertical directions will allow air flow behind it which reduces the thermal performance of the wall significantly.

Air from outside may penetrate the building envelope and extract heat from the house without contributing to the ventilation. The air flow paths behind the plasterboard of a heated semi-detached house in winter are shown in Figure 8. The heat loss rate associated with this air flow could be as much as 50 to 100 watts per wall on a cold day which is significant compared with 150 to 250 watts by conduction through a wall if the U-value is 0.35 to 0.5 $Wm^{-2}K^{-1}$ under the same temperature conditions.

The effect would not be so serious in a house with a solid floor and brick walls all round because most of the infiltration takes place at joins between dissimilar materials.

7. REFERENCES

1. Thorogood, R. P. (1979). BRE Information Paper IP 14/79. Resistance to Air Flow through External Walls.

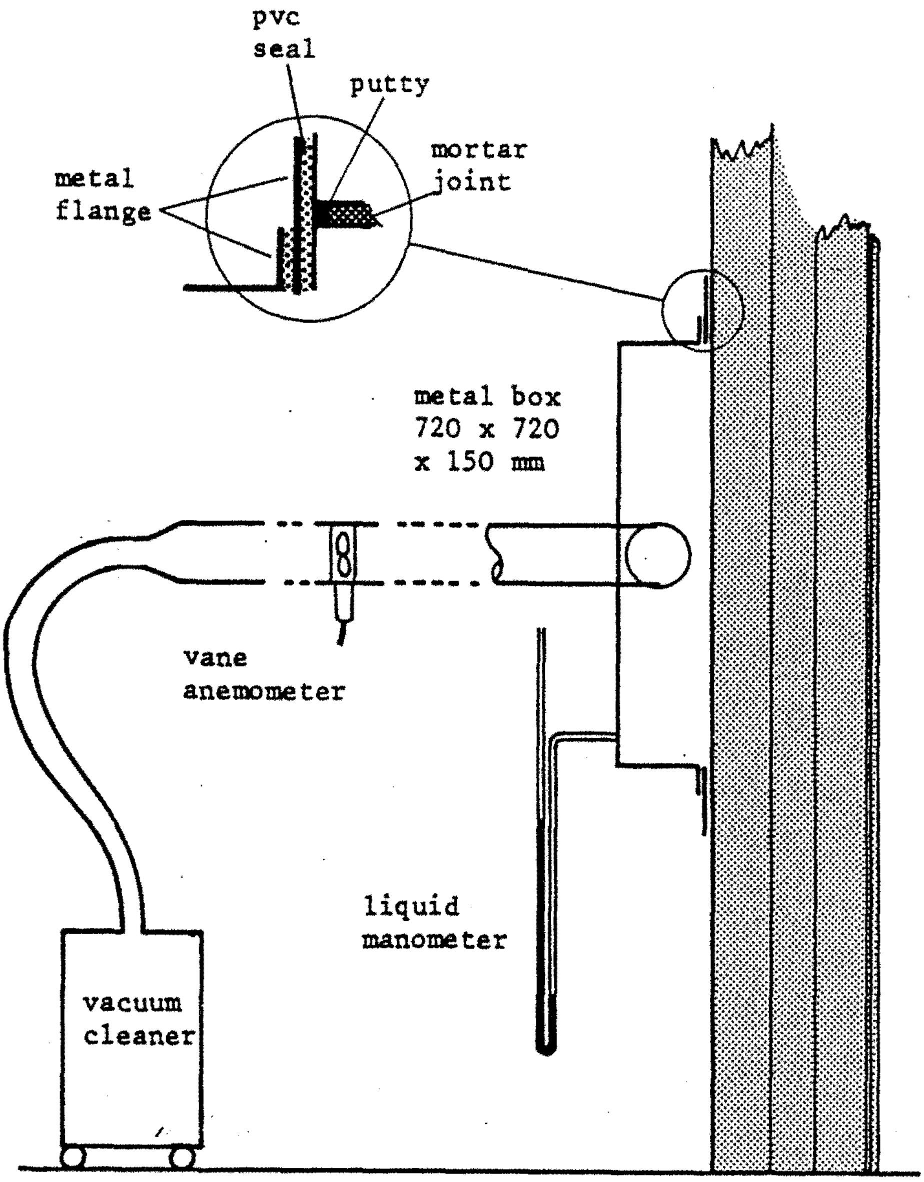

Figure 1   Wall permeability apparatus

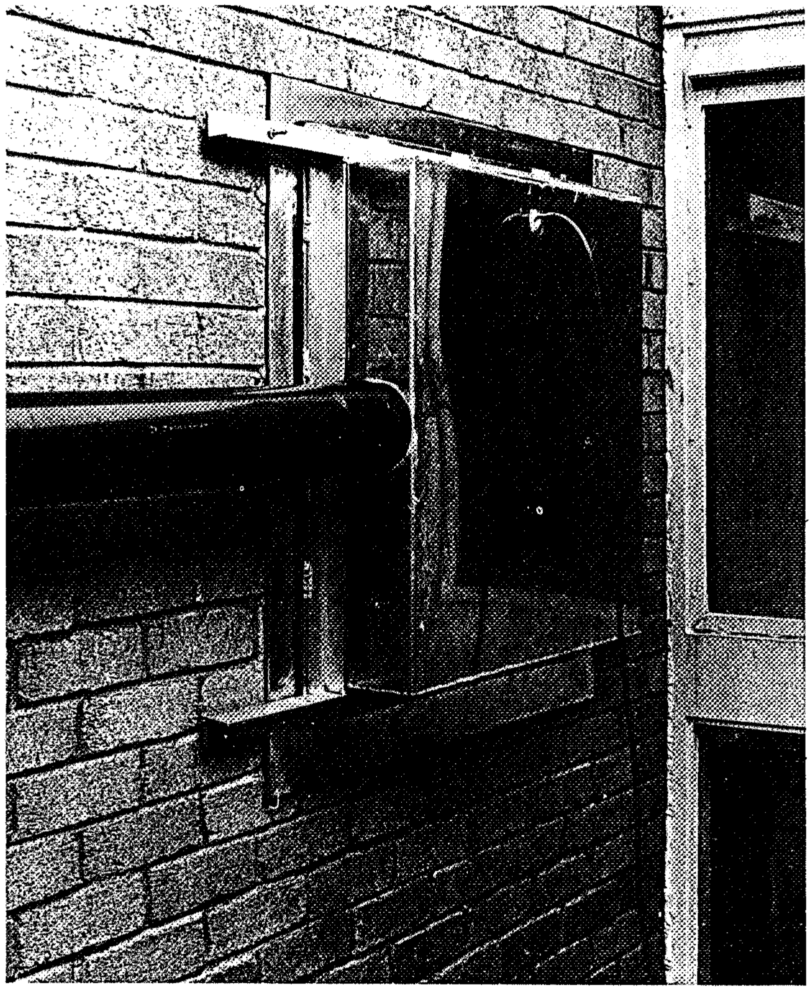

Figure 2.   Box clamped to wall

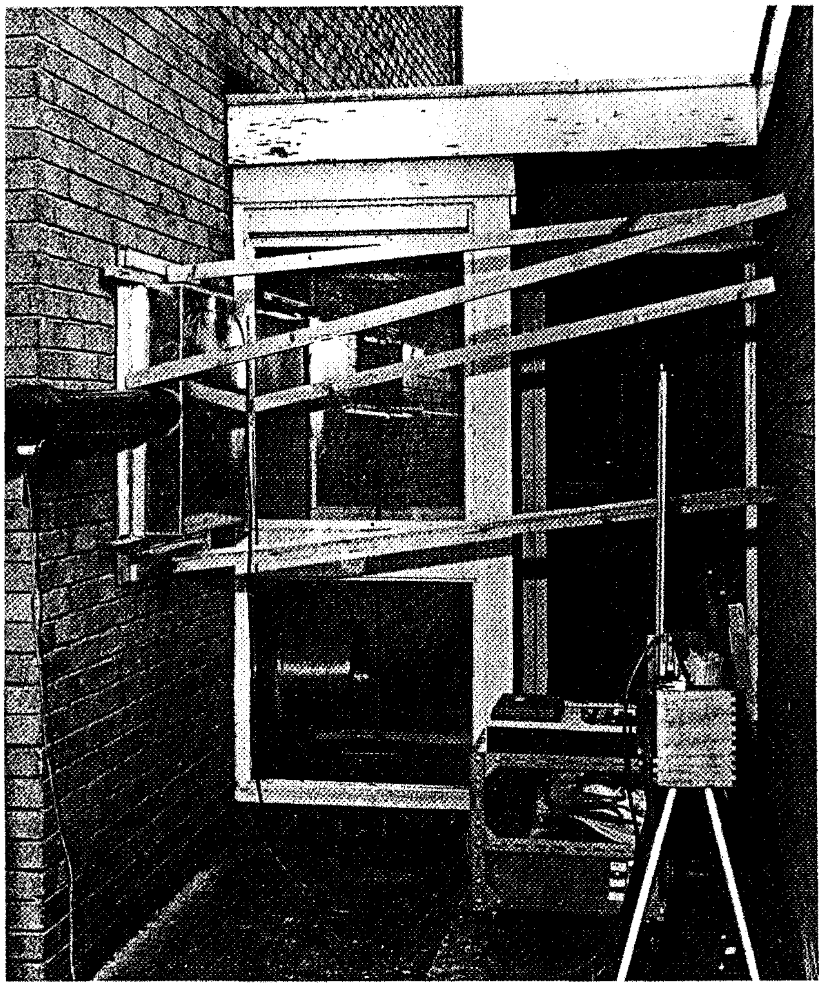

Figure 3. Permeability apparatus showing additional clamping pieces, vane anemometer and manometer

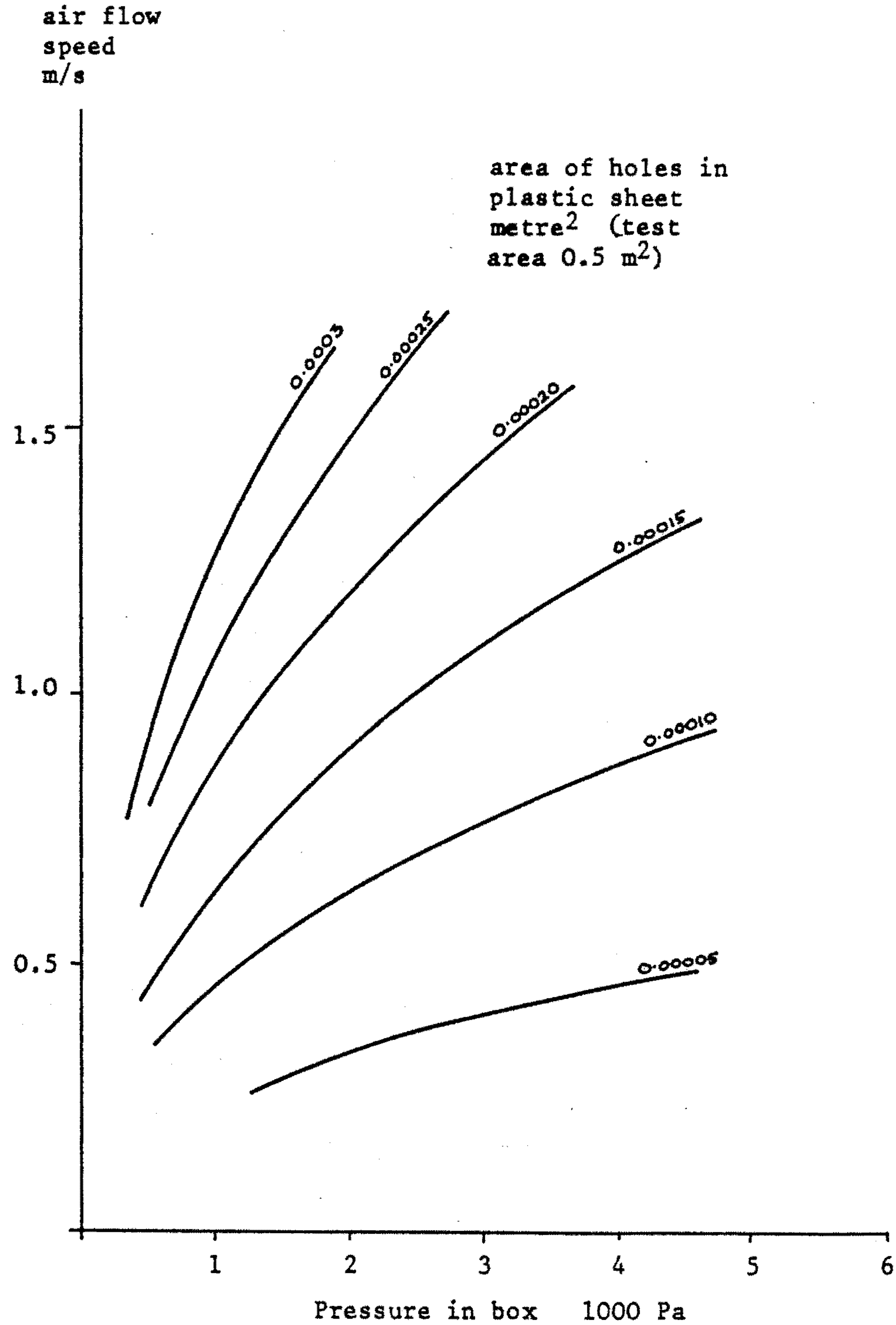

Figure 4. Effective leakage area calibration

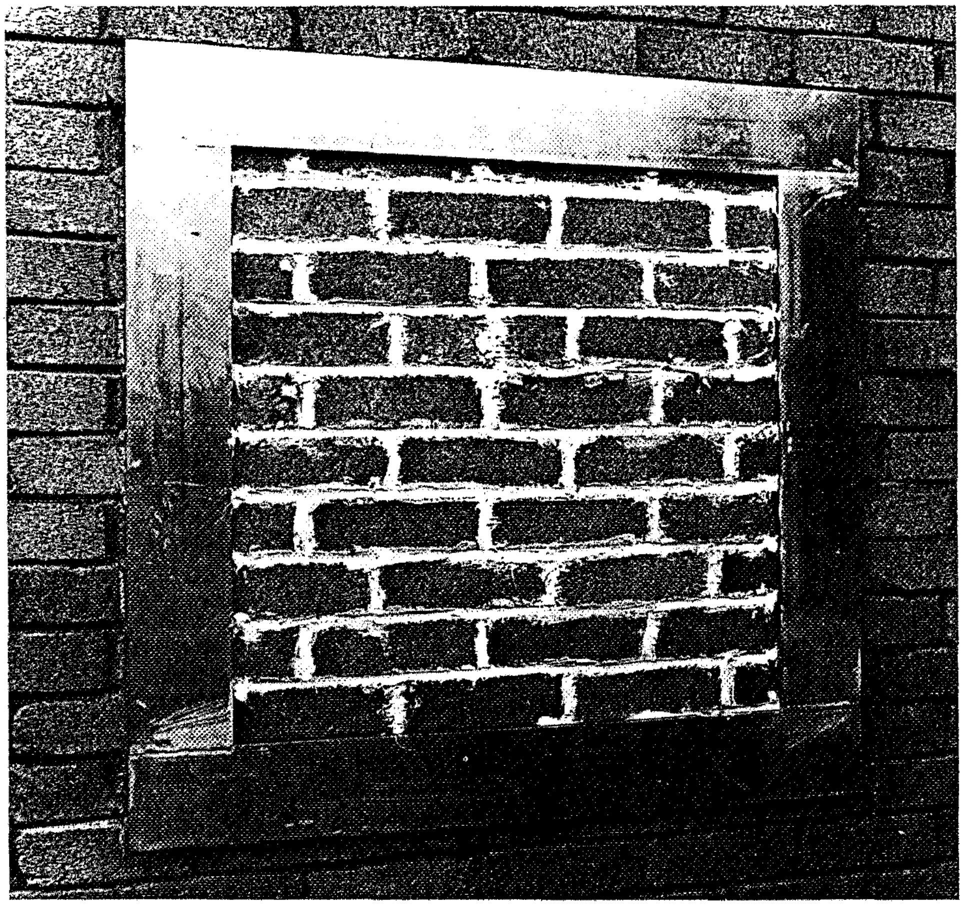

Figure 5. Mortar joints sealed with mastic

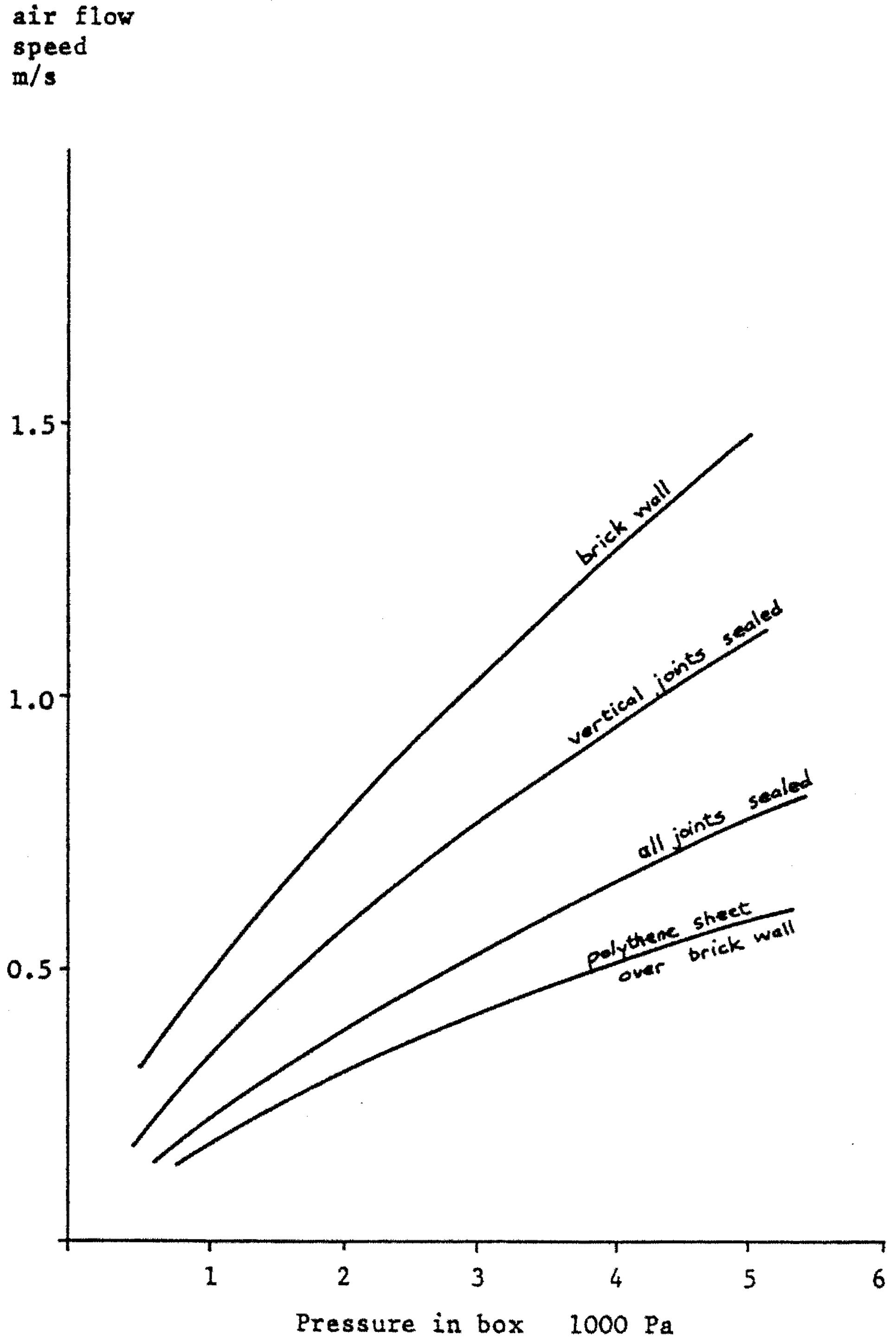

Figure 6. Leakage measurements of brick wall, see Figure 4 for calibration

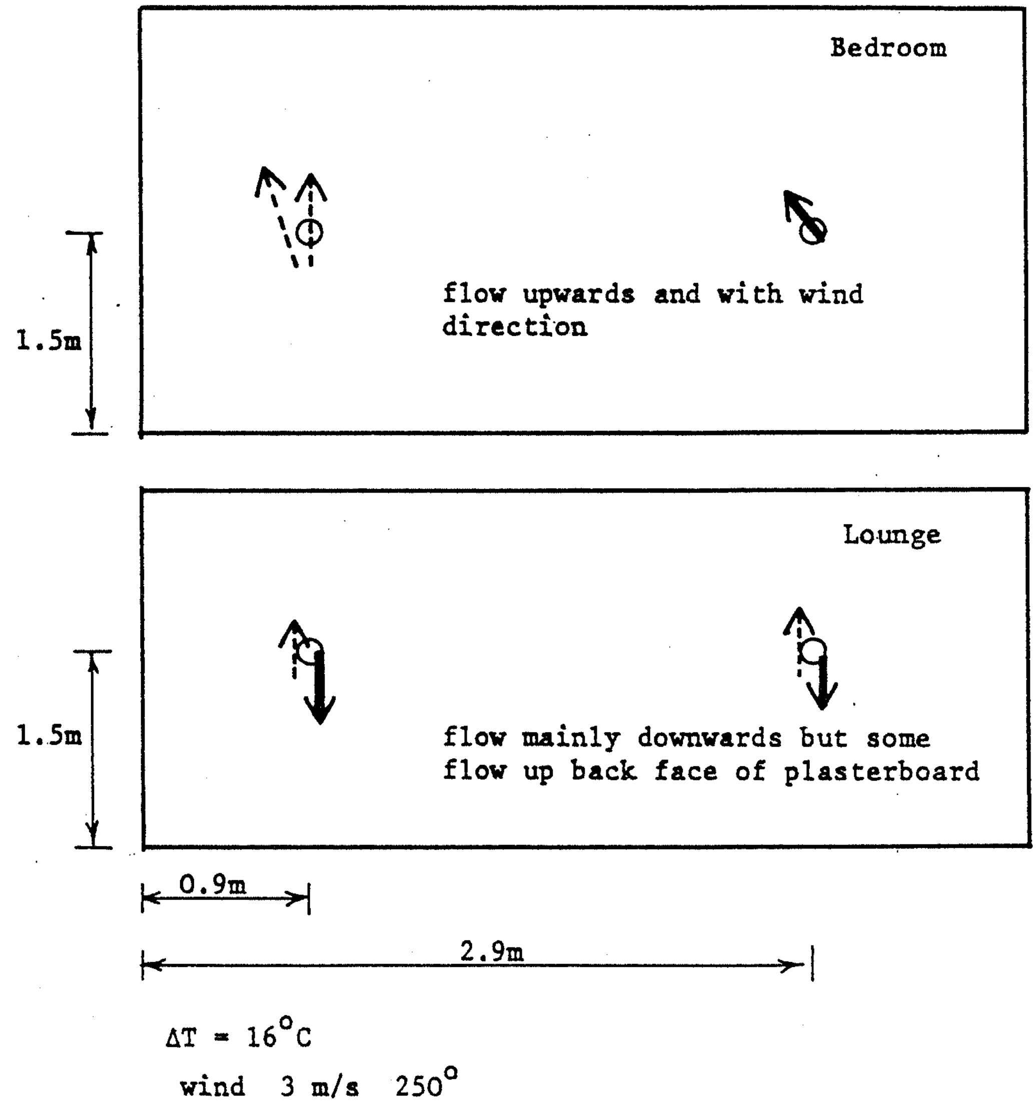

Figure 7. Observed air flow behind plasterboard dry lining of gable wall

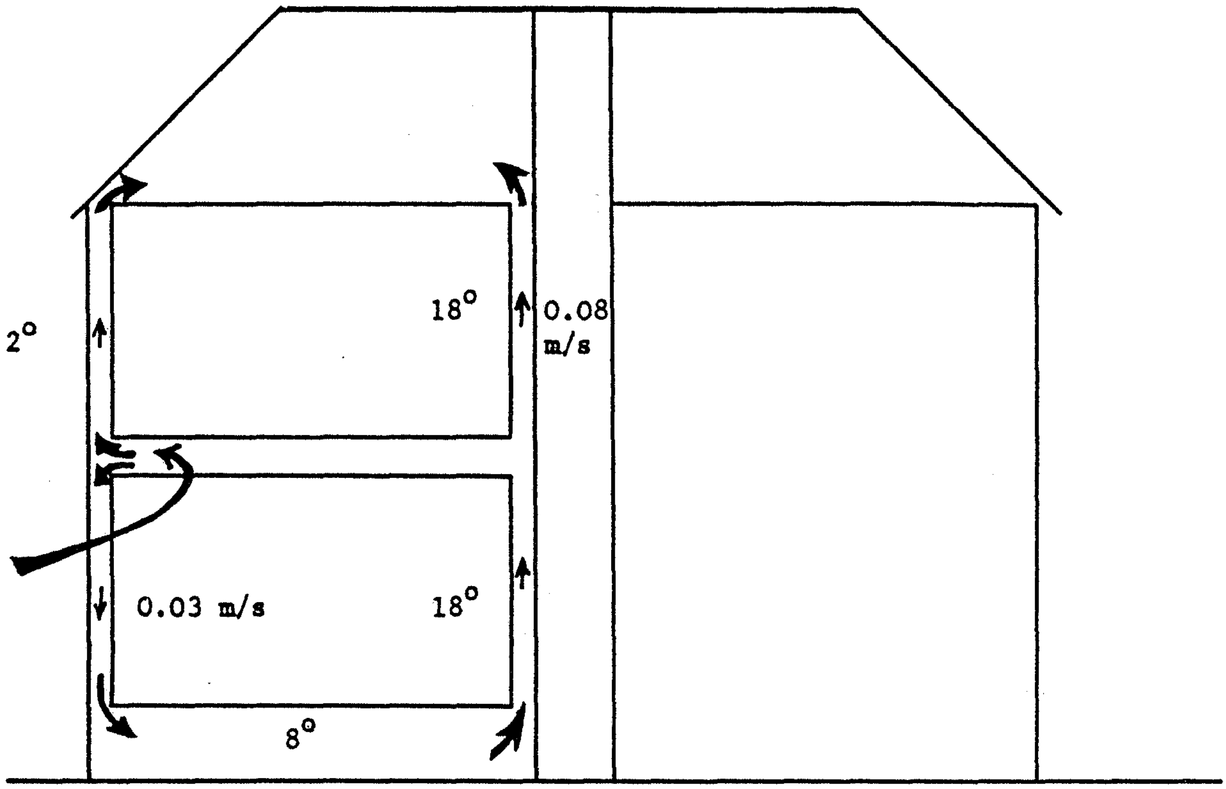

Figure 8. Air flow paths behind dry lining in a semi-detached house