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THE VALIDATION AND APPLICATION OF A PORTABLE PRESSURISATION TEST FACILITY FOR THE MEASUREMENT OF THE FLOW CHARACTERISTICS OF BACKGROUND LEAKAGE AREAS

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1. Introduction

The total air leakage of a house can be divided into 3 elements:

(i) specific ventilation openings (air bricks, fans)
(ii) identifiable component areas (doors, windows)
(iii) background leakage areas.

Measurements by several workers have indicated how whole house leakage areas are distributed. The early study by Skinner (1), together with more recent work by Warren and Webb (2), suggest that at 50 Pa pressure difference the background leakage area can represent 50% of the whole house leakage. At the more typical pressure of 5 Pa Warren and Webb found the background leakage to represent 25% of the total.

Background leakage cracks are not easy to identify and quantify. There is a lack of measured data for:

(i) the distribution of background cracks
(ii) the air flow characteristics of such cracks
(iii) the leakage paths for these cracks in buildings.

A better understanding and quantification of background leakage would yield several benefits. Firstly, it would be possible to identify those constructional elements which might be sealed during building for greater energy efficiency. Secondly, it might be feasible to establish a data set of the flow characteristics of typical building constructions and joints, analogous to the work of Reinhold and Sonderegger (3), who are trying to catalogue component leakage areas to enable leakage to be predicted from architectural drawings. Thirdly, it would allow more accurate computer modelling of inter-room air flows to be developed.

Background leakage must also be considered in very tight houses, either where mechanical ventilation plus heat recovery may be proposed or as a means of ensuring a minimum base ventilation rate for satisfactory air quality and moisture removal.

By definition or perhaps by default, background leakage areas are those which remain unsealed, because they are not easily identified or impractical to seal, during a conventional whole-house pressurisation test with progressive sealing off of the identifiable opening and component areas. Thus the individual contribution due to each background leakage path is unknown. The use of the pressurisation system, described below, which is capable of direct localised measurement can greatly aid the identification and quantification of individual background leakage areas.

2. The portable pressurisation test

The test uses the guarded pressure box principle (4) to measure the air flow through a specified target area under pressurisation. The whole room or house is pressurised using a blower door and a measurement box, pressurised by an auxillary fan, is placed over the target (Figure 1). The latter fan, if adjusted to maintain a zero pressure difference, $dP_o=0$, between the measurement box and the room, compensates for any disturbance of the leakage flow due to the presence of the measurement box and the connected volume flow meter. The resultant flow, Q, is the leakage due only to the target area at the pressure difference, dP, maintained across the building envelope.

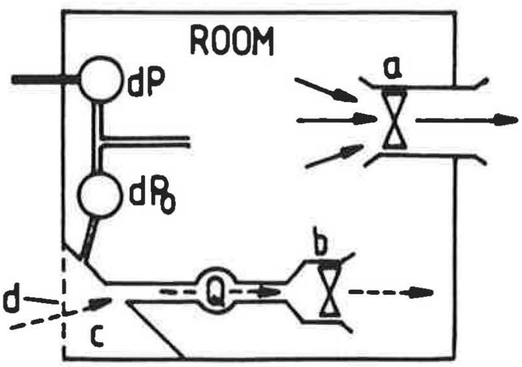

Fig. 1 Schematic diagram of test method. Fan (a) used to depressurise room to pressure dP, Fan (b) adjusted to maintain a zero pressure difference ($dP_o=0$) between the measurement box (c) and the room. The leakage flow (Q) through the target area (d) is then measured.

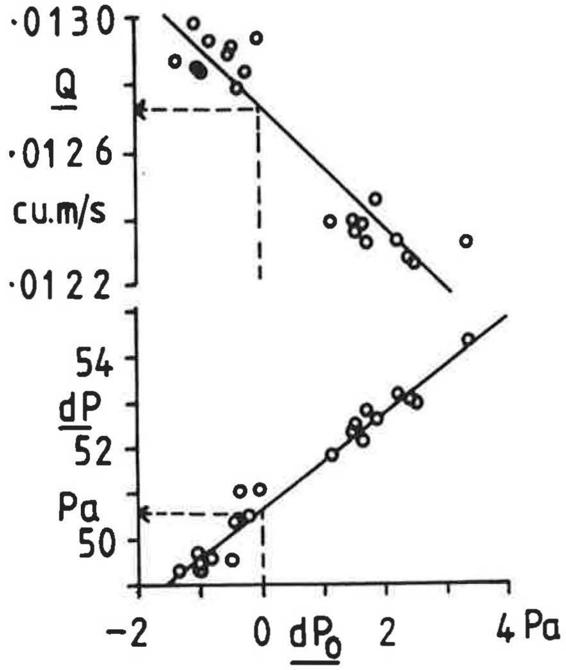

Fig. 2 Method for estimating Q and dP at $dP_o=0$

However, it is not neccessary, and in practice it is difficult, to equalise the measurement box and the room pressures to obtain $dP_o=0$, since it has been established by Siitonen (4) that for small deviation of dP_o from zero, produced by the fan system and low speed wind pressure effects, both the flow rate and the pressure drop across the target are linear functions of dP_o (Figure 2). The best estimates of the true flow rate and test pressure at $dP_o=0$ are obtained by calculating the intercepts by linear regression analysis of the measured values of Q, dP and dP_o taken for both positive and negative deflections of dP_o from zero, provided that dP_o can be minimised to within about 5% of the test pressure dP. The prototype test apparatus, shown in Figure 3, uses a microcomputer with a control/data acquisition interface to regulate the flow through the target area and thus achieve the necessary control of dP_o.

Earlier work (5) showed that measurements made over short sections of long uniform thin cracks are representative of the whole crack; similarly a non-uniform crack or junction may be traversed to give the total leakage by making measurements on adjacent sections using a small pressurisation chamber. A half-metre length box, fitted with a single flush fitting pressure taping, proved to be practical for this. The basic box can be adapted on site to fit the profiles of domestic leakage sites such as wall/skirting board/floor junctions using thin plywood sheet, tape, etc. Taping is only necessary to hold the box firmly in place during measurement; airtight seals are not required since the test compensates for adventitious flows. A "low-tack" tape which did not damage paintwork, etc. was used.

Any suitable flow meter which can be adapted to produce a voltage signal for data acquisition may be used. In the course of this work an orifice plate constructed to BS 1042 (6), and two commercial volume flow meters were used to cover the range of flows upto 50 cu.m/hour, the maximum delivery of the auxillary fan, with room pressurisation provided by a blower door, sufficient to pressurise 0.5m sections of most background cracks to at least 50 Pa. Regulation of the flow is accomplished with a simple valve driven by a bi-directional stepper motor controlled by the microcomputer.

A range of commercial self-zeroing manometers with analogue voltage outputs are used for pressure measurement. Automatic zero compensation is essential for the accurate measurement of dP_o.

During the test procedure, the pressure difference across the building envelope is set by the operator, who adjusts the blower door fan. The control system then automatically regulates the flow to minimise dP_o, reads Q, dP and dP_o, and calculates estimates of Q and dP at $dP_o=0$. The test pressure is then set to a new value by the operator. The characterisation of a target area by the measurement of the flows at ten pressure settings in the range 5-50 Pa can be made in 8-15 minutes including analysis and presentation of the data in a print-out. A quadratic relationship is fitted to the estimates of Q and dP at $dP_o=0$.

$$dP = a.Q + b.Q^2 \qquad (1)$$

where a and b are constants. The authors (5) found this to give a better fit to leakage data than the ubiquitous power law.

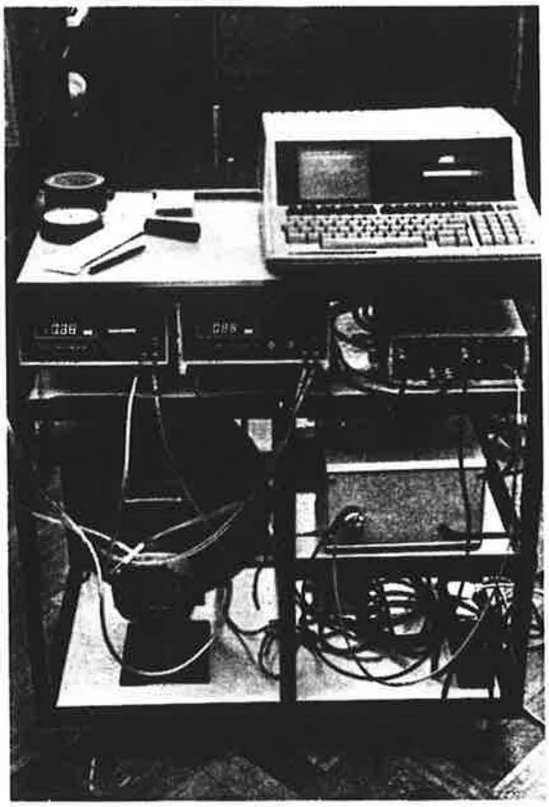

Fig. 3 The portable pressurisation test apparatus.

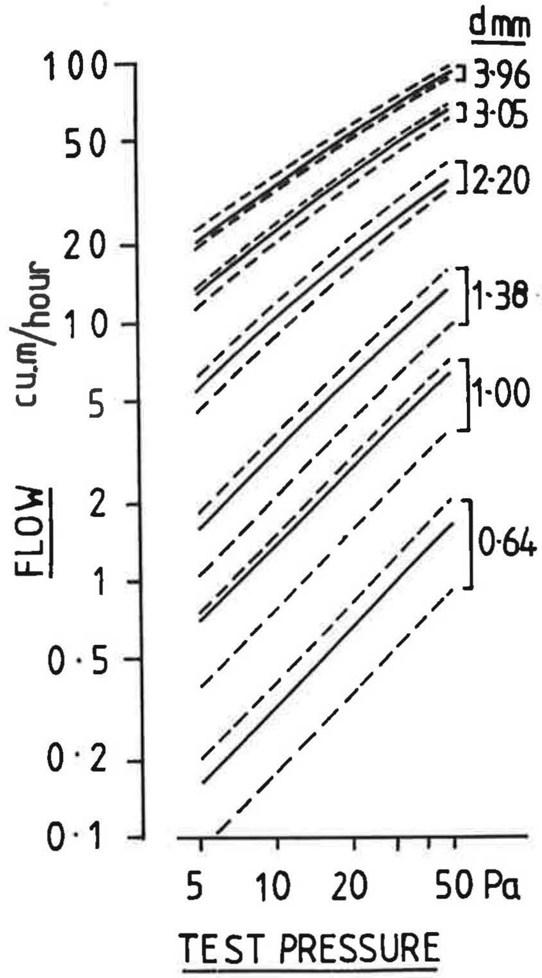

Fig. 4 Flow characteristics of full-scale model cracks (thickness, d): ========= predicted; ———— experimental (means of 10 tests)

3. Validation of the test against cracks with known leakage characteristics

Previous work (5, 7) showed that the experimental flow characteristics of uniform straight through cracks can be represented by the relationship

$$dP = 12\mu zQ/Ld^3 + 1.5\ Q^2\rho/2L^2d^2 \qquad (2)$$

derived from the theory of steady laminar flow through parallel plates, accounting for edge effects. L, d and z are the crack length, thickness and path flow distance, respectively. ρ and μ are air density and viscosity.

Six such cracks, length 1m, path distance 152mm, and thicknesses in the range 0.5 to 4mm, were used to provide standards against which the portable test was assessed. Since absolute uniform was not achieved during fabrication, the predicted flow characteristic of each crack according to Equation 2 is shown in Figure 4 as a band based on the standard deviation of its mean crack thickness.

The portable test was used on the central 0.5m section of these cracks. The results, scaled-up to give the flow rate per metre of crack length, are in good agreement with the predicted behaviour (Figure 4). The reproducibility was excellent: the standard deviation of the mean flow rate at a pressure difference dP measured over 10 trials on the same crack was typically less than 2% for cracks with d>=1mm. However, for the thinnest crack with d=0.64mm the uncertainty was greater and was associated with very low flow rates: the standard deviation of the flow rate varied between 2.5% at 50 Pa and 8% at 5 Pa.

4. Application of the test

The validity of the test thus established, it was used on background leakage areas produced by known construction defects. The leakage sites had previously been surveyed (8) by infra-red thermography combined with whole room depressurisation, which had indicated the comparative severity of the infiltration through these areas, but the technique could not quantify the infiltration rates.

4.1 Trial 1. A full-scale test wall

Leakage measurements were made along sections of a full-scale test wall of timber frame construction, built onto a test room in an environmental chamber. The thermographic survey had qualitatively distinguished between perfect (Figure 5) and typically defective detailing. The main series of pressurisation tests were made along adjacent sections the floor/wall junction using a 0.5m pressure box tailored to fit closely to the skirting board profile. The results are shown in Figure 6.

The trial distinguished correctly between perfect and defective detailing, with the apparent exception of the perfect section C. However, inspection of the fit of the skirting board and feeling the draught through any gaps at higher test pressures revealed a looser fit at C than at adjacent section B, the latter containing the worst defect. The worst leakage location was consequently found at section C. The construction detail (Figure 5) indicates that a continuous leakage path is formed by the floor movement gap and the gap below the plasterboard, thus air is able to flow from the defect site into the room through any gaps in the skirting. The leakage rate is probably a function of the skirting gap width and the distance of the gap from a defect site causing a breach in the building envelope.

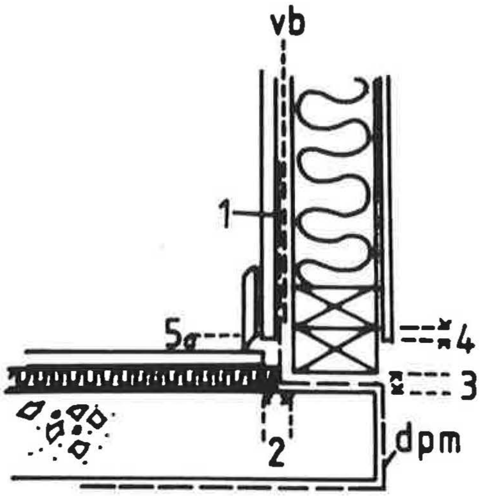

Fig. 5 Floor/wall junction
(not to scale)
1. v.b./d.p.m. overlapped 150mm and taped
2. 10mm floor movement gap
3. 20mm mortar soleplate bed
4. Plywood sheathing overlaps soleplate 10mm
5. Plasterboard 10mm above floor

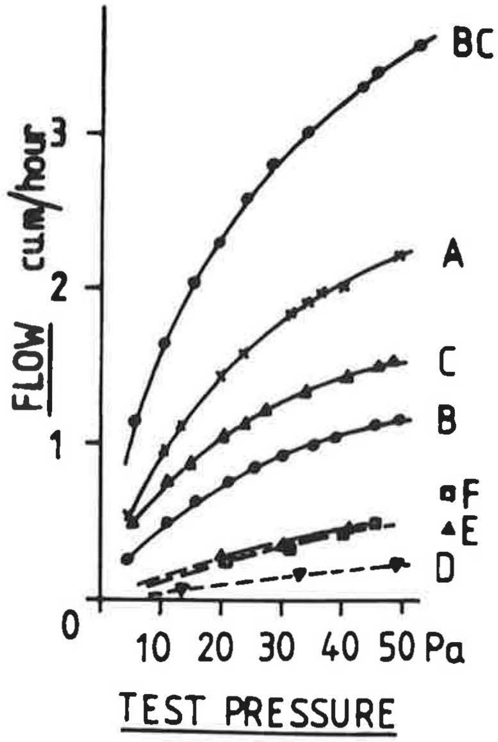

Fig. 6 Flow characteristics of ½m adjacent sections along test wall:
A. contains d.p.m./v.b. discontinuity
B. as A with void mortar bed
C. perfect construction but loose skirting board
D. plywood sheathing 10mm short
E. as D
F. perfect construction
BC. worst location, adjoining section between B and C.

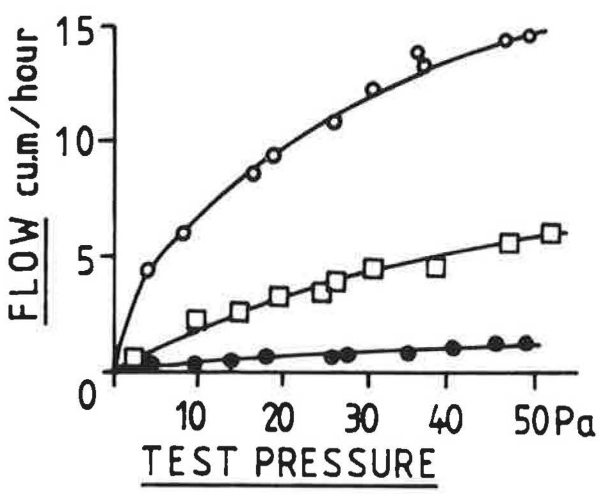

Fig. 7 Flow characteristics of ½m sections in ceiling of single storey buildings

o Ceiling/external wall junction

□ Ceiling/internal wall junction

● Ceiling tile/ceiling tile join

The low leakage rates through sections D, E and F correspond with the tighter fit of the skirting board along this section of the test wall; the shortened plywood sheathing behind D and E does not provide a leakage route through the wall.

4.2 Trial 2. On site: tests in a single storey building

The building has a pitched roof with eaves ventilation and a suspended tile ceiling, backed with insulation. The results of the thermographic survey in a typical unit of the building had clearly identified the main defects in the construction detail, also shown by visual inspection of the eaves space:

(i) insulation poorly laid or missing around electrical services entry points into the ceiling, around ceiling suspension wires, and at wall/ceiling junctions
(ii) gaps of upto 5mm at the wall/ceiling junction
(iii) gaps between ceiling tiles, but smaller than those identified in (ii).

The measured air change rate of the surveyed unit was 11 a.c.h. at 15 Pa, which is indicative of the poor energy performance of this building.

The leakage characteristice of three typical locations are shown in Figure 7. The high leakage rates indicate the severity of these defective junctions: the estimated infiltration rate due solely to the wall/ceiling gaps, based on the leakage data, is 5 a.c.h. at 15 Pa, nearly 50% of the whole-unit air change rate.

5. Discussion

The use of the portable pressurisation test in the above trials enabled better identification of the leakage routes than thermography alone. For example, although the thermographic survey generally provided a guide to the locus of the more severe infiltration sites, it proved unable to locate the leakage path through section C of the test wall. A complete leakage survey of a building would, however, be time consuming. The use of thermography to firstly identify significant infiltration areas, followed up by selective leakage measurements is thus suggested to provide the maximum of useful information for a practical survey duration. These data, combined with a knowledge of the construction details, could then be used to give some indication of the repair required or, at least, the future design modification necessary to avoid infiltration. Taking the test wall in Trial 1 as an example: a mastic seal along the continuous path formed behind the skirting board by the floor movement gap would prevent infiltration due to inadequate overlapping and sealing of the vapour barrier and damp-proof membrane during construction.

The proven accuracy of the test against the full-scale model cracks and its speed of operation make it suitable for the measurement of the flow characteristics of background and component leakage areas. However, Baker (9) has shown that wind induced pressure fluctuations increase the uncertainty of the leakage data as the wind velocity increases. The test is not recommended for use at wind speeds much in excess of 5 m/s, which gives an uncertainty level of about 10% in the estimation of leakage.

6. Acknowledgements

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7. References

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