OPTIMUM VENTILATION AND AIR FLOW CONTROL IN BUILDINGS

17th AIVC Conference, Gothenburg, Sweden, 17-20 September, 1996

CALCULATION METHODS FOR THE DETERMINATION OF AIR FLOW RATES IN DWELLINGS

Andrew Cripps

Building Research Establishment
Garston, UK

Calculation Methods for the Determination of Air Flow Rates in Dwellings

by Andrew Cripps, BRE

The members of CEN TC156, WG2, Ad Hoc Group 4, on whose work this paper is based are

V Dorer, Switzerland
P Barles, France
A Blomsterberg and T Carlsson, Sweden
A Cripps, UK
W de Gids, The Netherlands
E Kukkonen, Finland
J-G Villenave, France

Abstract

Ad Hoc Group 4 of Working Group 2 of CEN TC156 (Ventilation) was set up to put forward standardised techniques for estimating ventilation rates in dwellings. The purpose of the standard is to ensure that different people carrying out calculations with the same input data will obtain the same result. This will allow the use of these results in energy, heating load, IAQ or other calculations.

The methods proposed use two different techniques, an explicit and an implicit one. The explicit one involves more approximations, but can be carried out with a hand calculator. The implicit one requires the use of a computer.

This paper explains the methods used, justifies the approximations made and gives examples of the use of the explicit method. These show that the explicit method gives results in good, but not perfect, agreement with experiment, and also that the method is simple to use.

Introduction

The Ad Hoc Group 4 of CEN TC156, Working Group 2 was set up to develop a simplified method for ventilation calculations. The purpose is to ensure that people working with the same data in different places will achieve the same result. This is not likely if they use different models, or the assumptions used by each are not made clear.

Ventilation calculations are needed within three other tasks:

- Energy use predictions
- Air quality estimates
- Heat load calculations

Because of the differences in the applications each type of calculation has a different requirement for weather data, although the basic calculation is the same. For average energy calculations something close to average weather conditions must be used. For air quality, weather data with a low wind speed and a low temperature difference would be used, whilst for heat load calculations a 'worst case' weather situation will be used.

It is expected that other CEN standards will refer to this proposed standard when they need to include the ventilation rate as a component of their calculation. This will apply particularly to calculations of energy use in buildings, which currently use a very simple algorithm for ventilation rate, and to a proposed CEN standard on the design of residential ventilation systems.

In order to make a simplified model many assumptions have to be made. These are made when the input data are considered, and in the design of the methods. The input data are discussed in the next section. The following section describes how the explicit method is used, including the assumptions made within it. The implicit method is presented next, with the minimum of detail as it is based on other models. Finally some examples of how the explicit method has been used are given, and the implications for the future are discussed in the conclusions.

Input data required

To calculate the ventilation rate using either method the following data are required. If they are not available then they need to be estimated, and this must be made clear in the presentation of the results.

Building and dwelling:

- the type of building,
- the building height,
- the degree of shielding from the wind,
- the number of facades of the dwelling which are exposed to the wind,
- the air leakage rate of the dwelling (or the n_{50} value and the volume),
- the distribution of the air leakage over the envelope.

Ventilation system:

- the type of system (natural, mechanical extract or mechanical balanced system),
- the capacity of the ventilation system,
- - natural ventilation openings and duct terminal heights,
- - mechanical flows,
- the time these provisions are used.

Finally the climatic data have to be known:

- wind speed,
- external temperature
- internal temperature (measured or assumed).

Within the draft standard there is a lot of guidance on values of these for default cases. None of this is discussed further here.

The Explicit method

The idea of the explicit method is that it can be carried out easily using a pocket calculator or in a very simple spreadsheet. In order to achieve this there are a number of assumptions which need to be made. These are discussed below.

Both of the explicit and implicit methods are based on widely used air flow equations for a single zone model. These include equations for leakage flows, the flow rates through openings and the pressure differences generated from the wind and stack effects. These are not discussed further here. However the explicit method has to take some extra assumptions to avoid the need to use an iterative solution method.

1. Because the leeward side has a greater area than the windward side it is assumed that the air flow is dominated by the leakage of the windward side.
2. There is an effective pressure difference across the windward side, which is a summation of windward and leeward pressures. The internal pressure is assumed to be close to the leeward side pressure.
3. Default values for wind pressure coefficients, valid for a wind sector of approximately $\pm 60^o$ to the facade axis, are given in the standard. The wind direction is not considered more specifically.
4. The impact of the distribution of surface leakage is accounted for by correction factors calculated by comparison with a single zone model.
5. Flow rates due to the wind and stack components are added in quadrature.
6. Airing is treated as a single sided, single room ventilation effect through open window and doors. Cross-ventilation effects are not considered.

Using these assumptions the calculation becomes a series of straightforward steps, the outline for which is shown in figure 1. This shows the order in which the flows are calculated and then combined to give the totals. Although there are a number of stages to this calculation, in many cases several of them may not be present. In the Examples given later the BRE case only required the infiltration flow, qv-inf, as all the other flows were zero. For details of the equations and the details of the input data needed see the draft standard [1], available from Viktor Dorer at EMPA in Switzerland.

Internal flows in an apartment (i.e. flow from the staircase area of an apartment block into the apartment), combustion induced flows and room to room flows within a dwelling have also been considered, but are not addressed in this paper.

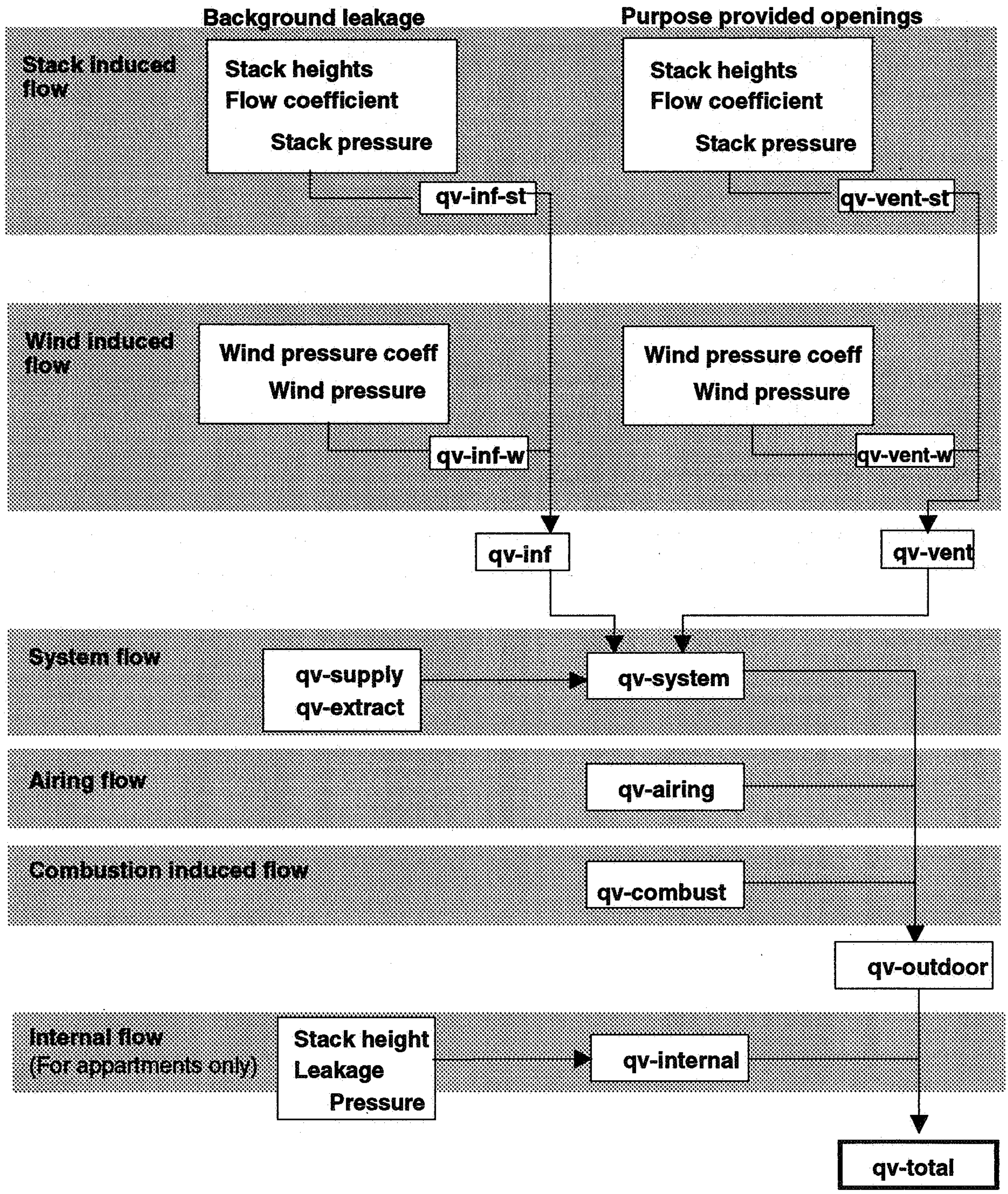

Figure 1: Calculation flow diagram for the explicit method

The implicit method

This method is based on the widely used single zone model [2, 3, 4, 5]. This means that the dwelling is represented by one zone with one temperature and one pressure value. This zone pressure value has to be determined by an iterative process based on a flow balance equation of all the flows entering and leaving this zone.

Given the wide availability of computers the implicit method might be widely used as it will run easily on a very small PC or similar computer. However for some applications the explicit method is easier to use; for example it can be built into a spreadsheet for carrying out energy calculations, so it is not clear at this stage which method will be most useful.

Because the implicit method is widely understood, and not discussed in the examples below it is not taken further in this paper, but more information can be found in the draft standard [1].

Example 1: Swedish single family house

Thomas Carlsson and colleagues at SP in Sweden (the Swedish National Testing and Research Institute) have experimental measurements for a single family house in Sweden. They have also used the explicit method to estimate the ventilation rate from corresponding weather data. The house is described in figure 2.

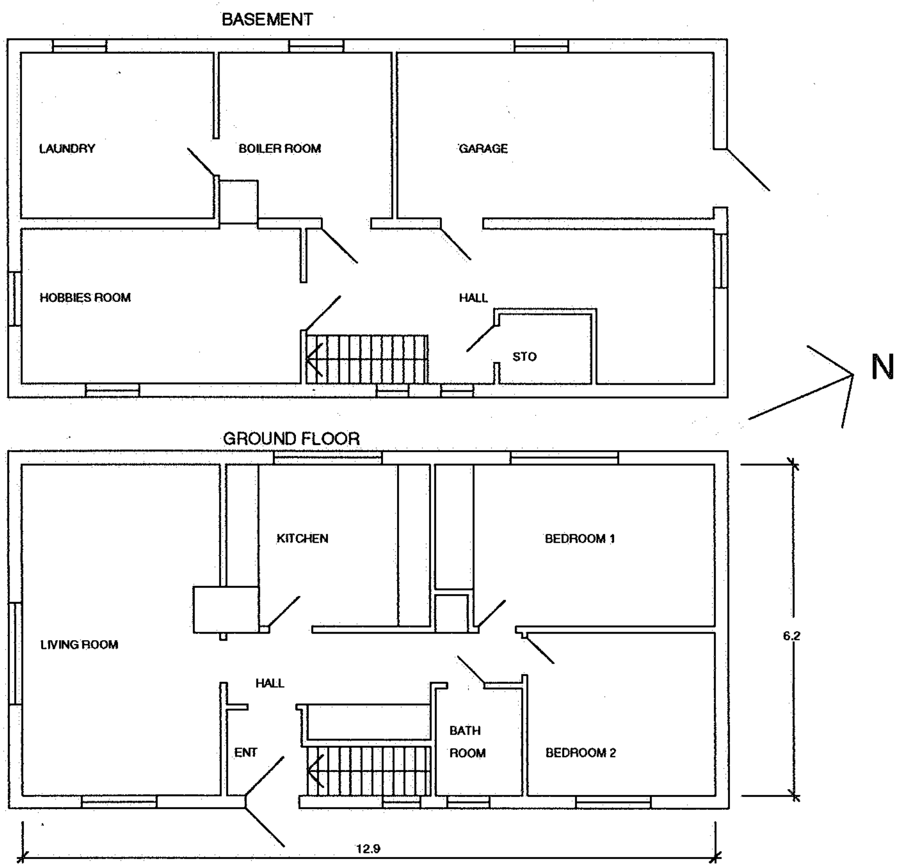

Figure 2: The floor plan of the Swedish test house

The data to be used for the calculation are as follows:

Building type	Single Family House
Roof slope	22°, i.e. in range 10°-30°
Ventilation system	Natural ventilation with passive stack, no vents
Overall leakage	7.8 ach, exponent n = 0.79
Building height	5 m
Volume	277 m^3
Temperatures	18.8°C inside, 0.3 °C outside
Shielding	normal
Wind velocity at site	0.9 m/s

Using these data, and the equations from the draft standard the flows are found to be:

qv-inf-st = 12 l/s,
qv-inf-w = 4 l/s.

These stack and wind components combine to give a total predicted flow rate of

qv-total = 13 l/s.

The measurements taken by SP give a flow rate for these conditions

q-measured = 16 l/s ± 10%.

Therefore in this case the simplified model is giving a good agreement with the measured data, considering the small number of input data used.

Example 2: Swedish multifamily building

The method has also been used on 2 apartments within a multifamily building in Sweden. A diagram of the apartment within the building is shown as Figure 3. The building is slightly complex in form, with a bend in the centre of around 70°.

The basic data are the same for both apartments:

Building type	Two room apartment in 4 storey building, with vertically open staircase
Roof slope	> 30°
Ventilation system	Natural ventilation with passive stack and vents
Building height	14 m
Shielding	Open

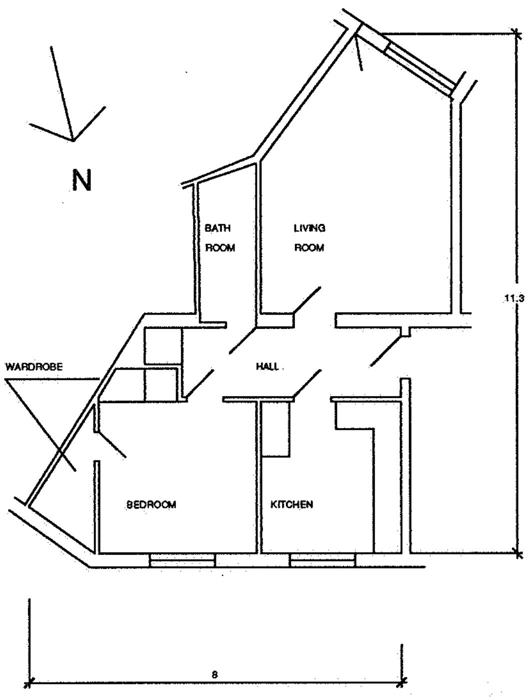

Figure 3: Floor plan of apartment within multifamily building

There are measurement results available for a flat on the second floor, and another on the fourth, and these are presented separately, along with the case dependent data.

Second floor apartment

Overall leakage 2.2 ach, exponent n = 0.86
Volume 139 m^3
$H_{inf} = H_{vent}$ 10.5 m (the effective stack height, which depends on the passive stack)

	Cold set	Mild set
Internal temperature, °C	19.3	24
External temperature, °C	-0.9	14
Wind speed, m/s	0.9	1.3
Predicted flow, l/s	25	18
Measured flow, l/s	35 ± 10%	32 ± 10%

Table 1: Data and results for second floor apartment

Fourth floor apartment

Overall leakage 1.8 ach, exponent n = 0.71
Volume 134 m^3
$H_{inf} = H_{vent}$ 5.1 m (this is the effective stack height, and depends on the passive stack)

	Cold set	Mild set
Internal temperature, °C	19.2	22
External temperature, °C	3.1	22
Wind speed, m/s	1.4	1.4
Predicted flow, l/s	17	8
Measured flow, l/s	24 ± 10%	19 ± 10%

Table 2: Data and results for fourth floor apartment

These results are not as good as the one for the single family case. In particular the model under-predicts significantly when the stack effect is small compared to the wind, as is occurring in each of the 'mild' cases. This suggests that there is a problem with the assignment of the pressure coefficients in the simplified model. It is not clear if this is really an error in the model or a detail caused by the geometry of the building. The building in which the apartment is located is not a simple shape, it includes a 'bend' of close to 70 ° in the middle, and this cannot easily be accounted for in such a simple model.

Example 3: BRE test house

The third example comes from one of the BRE low energy test houses which are discussed more in a paper by Hartless presented at this conference [6]. These data come from one of a matched pair of typical UK houses for which continuous monitoring of ventilation rates and weather variables have been taken over several years. Two extracts from this monitoring are considered here.

Building type	Single Family House
Roof slope	>30°
Ventilation system	Natural ventilation no passive stack, vents closed
Overall leakage	13.8 ach, exponent n = 0.62
Building height	5 m
Volume	207 m^3
Shielding	normal

This particular house has a relatively leaky floor above a ventilated void, which is quite a common construction type in the UK. Because of this an extra compensation factor was needed since the model was developed assuming low flow rates through the floor. Because the weather data are collected at half hour intervals it is possible to plot the measured ventilation rates against the predictions from the model. The first period is from July 1995, the second from March 1995.

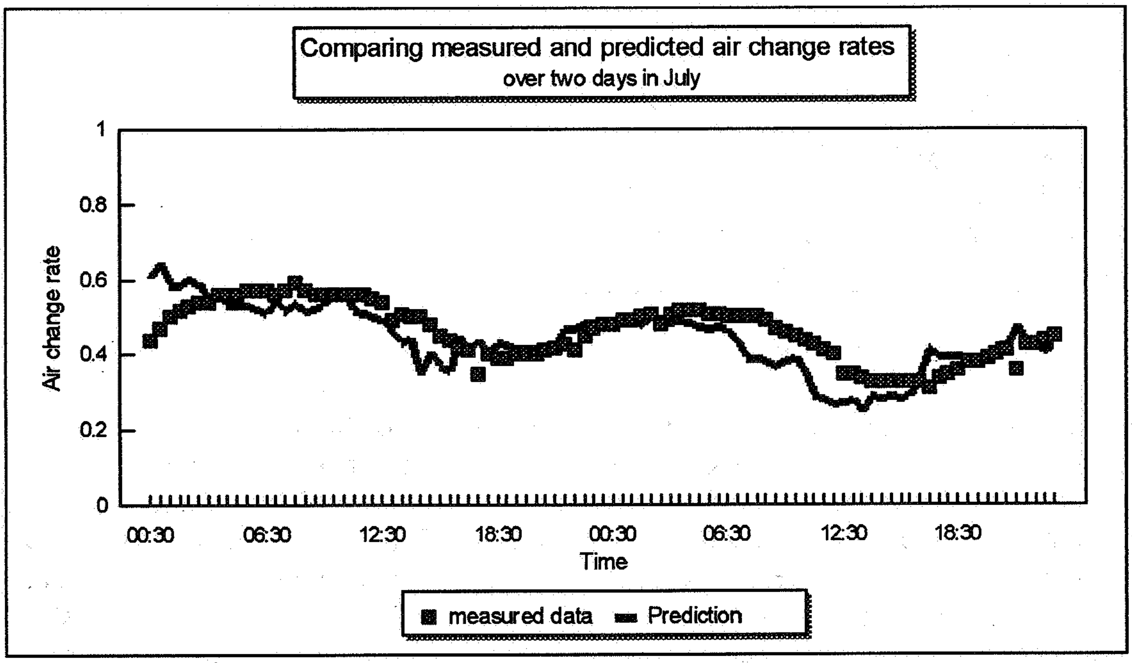

Figure 4: Graph of predicted and air change rates against time: data from July

These results are particularly good with close correlation between the measured and predicted air change rates. This period had relatively low wind speeds, the average measured on site being 2.5 m/s.

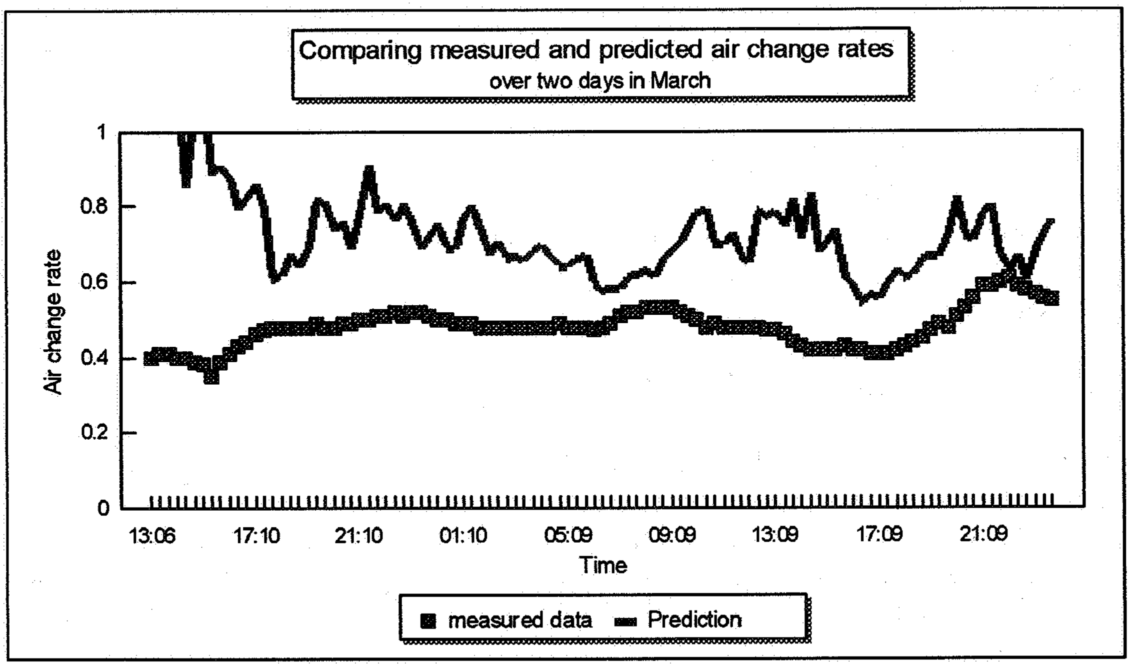

Figure 5: Graph of predicted and air change rates against time: data from March

In the second set presented as Figure 5 the wind speeds were much higher, with an average of 5m/s. The correlation here is much worse and this suggests, as with the earlier Swedish results, that there is more work to be done on pressure coefficients. However it should be noted that Hartless in his work [6] used a computer based single zone model and had the same problems modelling the March data.

Conclusions

In this paper the Draft CEN standard simplified method for ventilation calculations has been described and three examples of its use have been presented. These show that the model is easy and quick to use. It is the requirements of a standard that make the documentation needed rather long.

The examples show that the model gives results which have reasonable agreement to measured data where the stack effect dominates over the effect of the wind. As with nearly all models it has more trouble with the case when wind speed dominates, and more work is therefore needed on the pressure coefficients to be used.

The next step for the standard is for the draft to be considered again by Working Group 2 of the Technical Committee TC156. It is not too late to comment on the draft, but don't wait too long, as we are trying to complete the standard in the next year. Contact Viktor Dorer at EMPA for a copy of the current draft standard.

References

1 Draft standard CEN TC 156/ WG2/N203 *Calculation Methods for the Determination of Air Flow Rates in Dwellings*, 16. Oct. 1995, available from Viktor Dorer at EMPA, Switzerland.

2 Warren P R and Webb B C *The relationship between tracer gas and pressurisation techniques,* Proceedings of the first AIC conference, Windsor, UK, 1980, published by AIVC, UK.

3 Cripps A J and Hartless R P, *'BREVENT' A ventilation model,* BRE report AP66, December 1992, Published by BRE, UK.

4 Liddament M, *AIDA - an air infiltration development algorithm.* Air Infiltration Review, vol 11, no 1, Dec 1989.

5 Sherman M and Grimsrud D T, *Infiltration-pressurisation correlation: simplified physical modelling.* ASHRAE semi-annual meeting, Denver, USA, June 1980.

6 Hartless R P, *Subfloor and house ventilation rates: comparing measured and predicted values,* To be published in the proceedings of the 17th AIVC conference, Gothenburg, Sept 1996, by AIVC, UK.