Air Infiltration Review

a quarterly newsletter from the IEA Air Infiltration and Ventilation Centre

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AIVC Survey of Current Research into Air Infiltration and Related Air Quality Problems in Buildings

Peter Charlesworth, AIVC Scientist

Introduction

One of the main functions of the Air Infiltration and Ventilation Centre is to act as a review body for current world research and to ensure the full dissemination of this research throughout AIVC participating countries*. In order to fulfil this role the AIVC periodically undertakes a worldwide survey of research into air infiltration and related air quality problems in buildings. This survey, the fourth carried out by the AIVC and completed in 1986, was initiated by the distribution of a standardised survey form to organisations thought likely to be involved in air infiltration/air quality research. A total of 219 research summaries were received from organisations in 19 countries (see Table 1). This represents the largest response yet to an AIVC request for research information, and the assistance of all those who contributed is acknowledged with gratitude.

Structure of Survey

The analysis is presented in two sections. In the first section the results are analysed in terms of the various headings on the survey form:

- specific objectives
- project details
- building or building components
- parameters with which air infiltration and indoor air quality are related
- allocation of staff time.

Belgium, Canada, Denmark, Federal Republic of Germany, Finland, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States of America.

Inside this issue:

All the research summaries are presented in the second section. They are divided into two sub-sections:

- participating countries
- non participating countries.

Each project is identified by a reference number comprising a country identificaiton code followed by a number indicating the order in which it appears under the relevant country heading. The report also contains a list of principal researchers and organisation addresses. This acts as a directory of people currently involved in air infiltration/air quality research and indicates their current area of interest.

Analysis of Research Summaries

The research summaries were initially analysed in terms of their specific objectives. Fifteen categories of objectives were identified.

i) To develop/use/assess measurement techniques designed to evaluate air leakage, infiltration or air movement in buildings (65 replies).

ii) To develop/use/evaluate calculation techniques to predict air infiltration or air flow in buildings/building components (39 replies).

iii) To design or assess the efficiency of heating/ ventilating systems or ventilation strategies (38 replies).

iv) To develop/assess construction techniques/retrofit measures designed to reduce air leakage/energy consumption in buildings (34 replies).

v) To monitor indoor air quality in buildings (31 replies).

vi) To assess the effect of airtightness/air leakage/ ventilation on indoor air quality (23 replies).

vii) To determine the effect of indoor air quality/air movement on occupant health/comfort (19 replies).

viii) To study/assess sources/causes of indoor air pollution (15 replies).

ix) To develop/recommend airtightness and related guidelines (22 replies).

x) To determine the performance (heat loss, air leakage) of specific building components (16 replies).

xi) To determine the effect of occupants on air infiltration or to assess their interaction with heating/ventilating systems (15 replies).

xii) Overviews of research into air infiltration, air quality and related topics (11 replies).

xiii) To determine the factors which affect air infiltration and ventilation (13 replies).

xiv) To determine (predict/measure) building air pressure distribution (internal/external) (9 replies).

xv) Investigations dealing with combustion venting (5 replies).

The information regarding which projects lie within the bounds of each category is presented in tabular form, thus enabling the readers to identify the research summaries which are of interest to them. The summaries can then be examined in detail by consulting Section 2 of the report.

Researchers also provided detailed information about their projects. These project details have been summarised in terms of:

- experimental work
- tracer gas measurements
- indoor climate measurements
- theoretical work
- building occupancy
- heating and ventilation systems.

Once again, this information has been presented in tabular form. Thus the reader can, for example, easily identify those projects involving the use of the constant concentration tracer gas technique, or which researchers are using sulphur hexafluoride as a tracer gas.

For the first time in any AIVC survey, space was provided on the survey form for researchers to give specific information regarding the type of building/building component under examination. Finally, two tables are provided in the report which refer to the parameters to which air infiltration and air quality are related.

Information about the staff time allocated to each project was stated in 75% of the survey replies. This information is summarised in Figure 1. The median time allocation for each project is approximately 2000 hours, while the research effort for 75% of the projects is under 5000 hours. Thus, the time being expended on individual projects is in the region of between one and three person years. An analysis was performed of the distribution of projects among types of organisations. This revealed that approximately 41% of projects are being undertaken by government or public sector establishments, 36% by academic institutions and 23% by commercial or private sector organisations.

Participating countries			Non-participating countries		
Country	Identification code	Number of replies	Country	Identification code	Number of replies
Belgium	BE	8	Australia	AU	1
Canada	CAN	31	France	FRA	10
Denmark	DK	3	Hungary	HUN	3
Federal Rep. of Germany	FRG	5	Italy	ITL	2
Finland	FIN	12	Japan	JAP	9
Netherlands	NL	17	Poland	POL	1
New Zealand	NZ	1	Saudi Arabia	SDA	1
Norway	NOR	2			
Sweden	SWE	13			
Switzerland	SWZ	12			
United Kingdom	UK	45			
United States of America	USA	43			
TOTAL		192			27
GRAND TOTAL					219

Table 1: Origin and distribution of survey replies

Concluding Remarks

In terms of the total number of replies received, this survey represents the most comprehensive review of current research yet published by the AIVC. The project summaries essentially cover all aspects of air infiltration and air quality

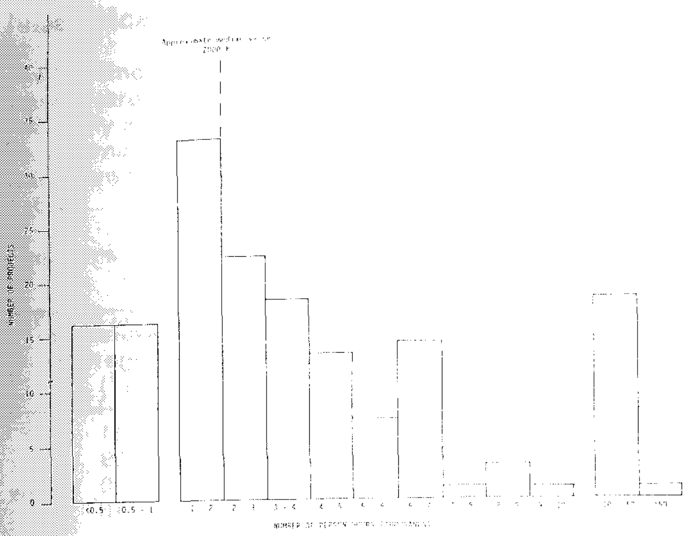
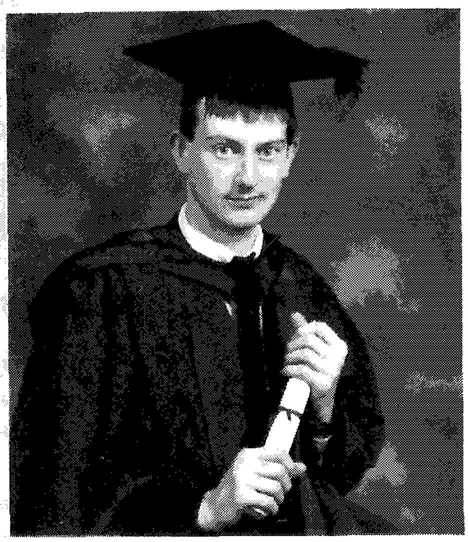


Figure 1: Allocation of staff time

research. It is of particular interest to note that two areas of weakness pointed out in the last survey (published in 1983) have seen a distinct improvement in the amount of research time allocated to them, i.e. occupancy effects (19 replies) and studies of various ventilation systems and strategies (38 replies).

Since the last survey there has also been a significant increase in work, both theoretical and experimental, dealing with inter-zone airflows in multi-compartment buildings. In the field of air quality research, much interest is currently being shown in the causes and sources of indoor air pollution and the effect this pollution has upon building occupants. The Air Infiltration and Ventilation Centre will continue to gather information about current research into air infiltration and air quality. It is envisaged that the next full survey and analysis of research will be carried out in 1989.

The full analysis of the 1986 survey is currently available from the AIVC, free-of-charge, to organisations in participating countries only. Details are given on the publications order form contained in this newsletter.



Phd. Award for Peter Charlesworth

Peter Charlesworth, AIVC Scientist, collected his PhD certificate from the chancellor of the University of Sheffield on 5th December 1986. The subject of his thesis was Heat Loss from Solar Collectors.

8th AIVC Conference

'Ventilation Technology – Research and Application'

21–24 September 1987
Parkhotel St. Leonhard, Überlingen, Federal Republic of Germany

Preliminary Notice

This conference will focus on recent developments in the application of air infiltration research. Of particular importance, the following key areas are covered:

- calculation techniques
- measurement techniques
- building construction in relation to air infiltration and air quality
- airborne moisture problems

Full programme and registration details will be published in the May edition of AIR, or can be obtained from your Steering Group representative. Please reserve the conference dates, 21–24 September 1987, in your diary.

Power Law Rules – OK?

Martin W. Liddament
Head, Air Infiltration and Ventilation Centre

Introduction

In air infiltration and ventilation calculations, a power law equation is frequently used to represent the characteristics of flow through openings. Such an equation takes the form

$$Q = k(\triangle P)^n \qquad m^3/s \qquad (1)$$

where Q = flow rate (m^3/s)

$\triangle P$ = pressure difference across opening (Pa)

k,n = flow coefficients

The flow coefficient, k, is related to the size of the opening and the exponent, n, characterises the type of flow. The flow exponent ranges in value between 0.5 for fully turbulent conditions, to 1.0 for laminar flow. In practice its value for cracks or adventitious openings tends to vary between 0.6 and 0.7. The validity of the power law approach is essentially based on the observed behaviour of flow at pressures in excess of those normally occurring under ambient infiltration conditions. This is because normal pressure differences (typically 0 – 5 Pa) are very low and it is difficult to make accurate field measurements in this range. However, there is some evidence to suggest that at these lower pressures, air flow is more accurately represented by a quadratic equation of the form

$$\triangle P = \alpha Q + \beta Q^2 \qquad (Pa) \qquad (2)$$

where α and β are flow coefficients.[1] Another preference of the quadratic form is that the equation is dimensionally correct throughout the flow regime, whereas the power law equation is not.

The object of this article is to compare the performance of these two flow representations against a small set of measurement data using the concepts outlined in the Air Infiltration and Ventilation Centre's Calculation Techniques Guide.[2] A particular aspect of the approach presented is that in each case an identical solution technique, flow network and pressure field has been applied, thus enabling a direct comparison of each of the flow representations to be made. The tests were by no means exhaustive and further evaluation is recommended.

Test Data and Flow Network

The test data were taken from a small subset of the data used in the AIVC's model validation exercise.[3] It relates to a fairly tight single family dwelling located on the edge of a small estate. A summary of essential data items is presented in Table 1. In terms of the power law equation, the flow characteristics of the building are given as

$$Q = 0.0168\,(\triangle P)^{0.71} \qquad (3)$$

Using the calculated flow rates at 30 Pa and 50 Pa, the equivalent quadratic equation is

$$\triangle P = 101.31Q + 310.14Q^2 \qquad (4)$$

On a 0 – 50 Pa plot (Figure 1a) the flow characteristics of each equation appear to be almost identical. However, in the critical 0 – 5 Pa regime (Figure 1b), the difference in flow prediction is substantial. At 1 Pa the quadratic flow prediction is 40% below the power law value. Clearly it is inevitable that ventilation and infiltration predictions will also differ substantially.

Building height: 8m
Volume of shielding: 386 m^3
Shielding conditions: see text
Flow characteristics: see text

Run No.	Inside/outside Temp. Diff. (°C)	Wind (m/s)	Measured air change rate (h^{-1})
1	7.5	3.84	0.11
2	13.0	3.35	0.09
3	26.8	2.19	0.20
4	26.2	4.43	0.16
5	28.1	5.63	0.20
6	29.9	4.69	0.19
7	29.1	5.68	0.18
8	32.2	5.23	0.20
9	33.9	5.99	0.20
10	33.5	6.30	0.21
11	37.5	3.84	0.19
12	40.5	5.23	0.21
13	40.6	5.86	0.21
14	17.5	1.07	0.10

Wind speed is measured on site at a level of 18m above ground.

Table 1: Summary of Test Data

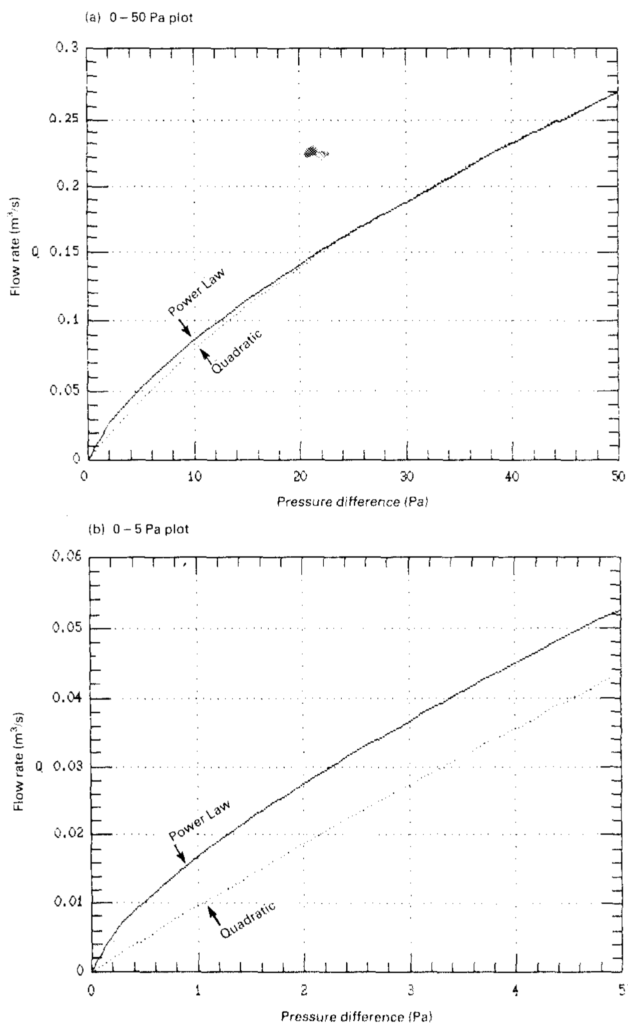


Figure 1: Comparison of power law and quadratic flow rates

Numerical Approach

The building was essentially approximated by a 'single zone' square structure in which the leakage was distributed uniformly about the exposed surface of the heated volume, i.e. external walls and top floor ceiling. Discrete flow paths were introduced on each face of the building as indicated in Table 2.

Equations (1) and (2) were applied to each flow path to yield

(i) Power Law

$$\sum_{i=1}^{j} k_i \, |p_i - p_{int}|^{n_i} \left(\frac{p_i - p_{int}}{|p_i - p_{int}|} \right) = 0 \qquad (5)$$

where k_i = flow coefficient of the i'th flow path

n_i = flow exponent of the i'th flow path

p_i = external pressure acting on the i'th flow path

p_{int} = internal pressure

j = number of flow paths

(ii) Quadratic

$$\sum_{i=1}^{j} \left(-\alpha_i + (\alpha_1^2 + 4ß_i \, |p_i - p_{int}|)^{1/2} \right) / 2ß_i \times \frac{(p_i - p_{int})}{|p_i - p_{int}|} \qquad (6)$$

where α_i and $ß_i$ = quadratic flow parameters of the i'th path

In both formulations the absolute pressure difference, $|p_i - p_{int}|$, is used in the power law or square root term. The true sign of the flow direction is restored by the last term of the equation.

The pressures driving the air change process were approximated by the wind and pressure equation

$$P_w = \frac{\rho}{2} C_p V^2 \qquad \text{(Pa)} \qquad (7)$$

where ρ = air density $\simeq$ 1.29 kg/m^3

C_p = wind pressure coefficient (depending on wind direction and shielding)

V = wind speed at building height (m/s)

and the stack pressure equation

$$P_s = -\rho_o g \, 273 \, h \left(\frac{1}{T_e} - \frac{1}{T_i} \right) \qquad \text{(Pa)} \qquad (8)$$

where ρ_o = air density at 0°C (~1.29 kg/m^3)

h = height of opening above lowest opening (m)

T_e = outside temperature (K)

T_i = inside temperature

The relevant wind pressure coefficients and height of openings are summarised in Table 2 where the wind pressure data have been taken from Section 6 of the AIVC Calculation Techniques Guide.[2]

Flow path no.	Leakage Site	*Height (m)	Wind pressure coeffic. (urban)	Wind pressure coeffic. (partly sheltered)
1	Front ground floor facade	0.0	–0.3	–0.33
2	Garage – NE facade	0.0	0	0
3	Garage – NW facade	0.0	0	0
4	NW ground floor facade	0.0	0.05	0.1
5	Rear ground floor facade	0.0	0.05	0.1
6	SE ground floor facade	0.0	–0.3	–0.35
7	Front first floor facade	2.6	–0.3	–0.35
8	NW first floor facade	2.6	0.05	0.1
9	Rear first floor facade	2.6	0.05	0.1
10	SE first floor facade	2.6	–0.3	–0.35
11	Ground floor 'flat roof'	1.4	–0.4	–0.45
12	First floor roof	4.0	–0.4	–0.45

*Level given with respect to lowest opening

Table 2: Flow Path Data

Shielding and Wind Speed

Surrounding shielding makes an important contribution to the net wind pressure distribution. For the purposes of this exercise it was assumed that shielding conditions would range between surrounding obstructions equal to the height of building, i.e. adjacent houses, and surrounding obstructions equal to half the height of the building, e.g. fences, walls, shrubbery, etc. In part this is dependent on wind direction but in this study both sets of conditions were applied in an attempt to illustrate the relative significance of this parameter. However, the most realistic shielding condition for this particular set of data was thought to be the 'half height' value. The shielding parameter is transferred to the infiltration calculation via the pressure coefficient, C_p, in equation (7). The applied values are presented in Table 2.

Since the strength of the wind increases with height above ground level, it is imperative that the correct building height windspeed is used in equation (7). Measurements were made within the locality of the building at a height of approximately 18m. Guidelines presented in Section 6 of the Calculation Techniques Guide were used to determine the necessary multiplication or 'wind reduction' factors, necessary to convert the measured wind speed to the 8m building height value. The resultant factors were 0.82 for the sheltered condition and 0.85 for the partly sheltered condition.

Simulations

In a single zone calculation, an internal pressure is evaluated such that the flow into the building is balanced by the out flow (equations 5 and 6). This is achieved by an iteration process in which an arbitrary guess at the internal pressure is successively amended until flow balance is achieved. The data summarised in Tables 1 and 2 were accordingly applied to equations (5) and (6) to produce four sets of infiltration calculations. These were:

i) Power law equation with half height surrounding obstructions

ii) Power law equation with equal height surrounding obstructions

iii) Quadratic equation with half height surrounding obstructions

iv) Quadratic equation with equal height surrounding obstructions

The corresponding results are presented in Figures 2 – 5 respectively.

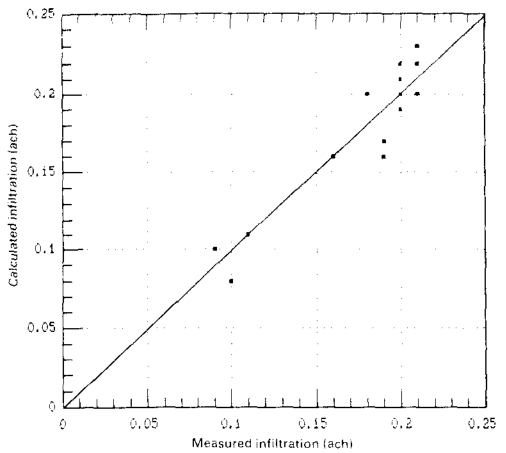


Figure 2: Calculated vs measured air infiltration Power law – 'half height' shielding

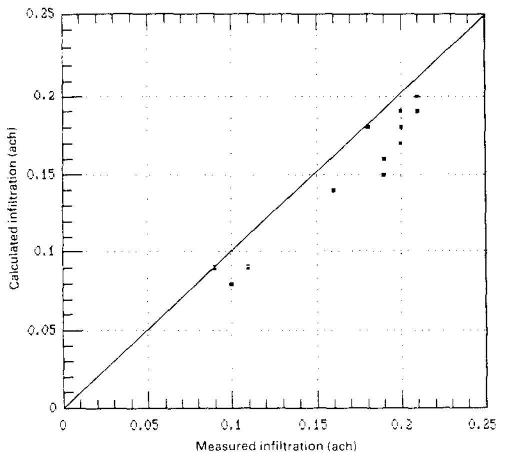


Figure 3: Calculated vs measured air infiltration Power law – 'equal height' shielding

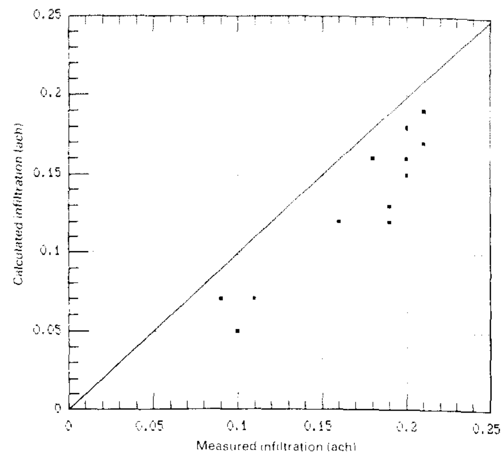


Figure 4: Calculated vs measured air infiltration Quadratic law – 'half height' shielding

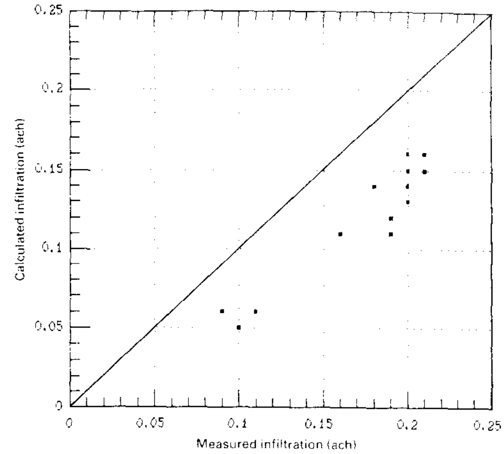


Figure 5: Calculated vs measured air infiltration Quadratic law – 'equal height' shielding

Results

Figure 2 illustrates the comparison between calculated and measured air infiltration using the power law with half height shielding. Calculated values were fairly evenly distributed about the line of perfect agreement and all the calculations were well within ±25% of the measured values. Figure 3 illustrates the power law results for equal height surrounding shielding. Again, all results are within 25% of measurement but they are below the measured infiltration rates. The quadratic law results with half height shielding are presented in Figure 4. These all underestimate the observed values with four of the data points diverging from the measured values by more than 25%. Finally the quadratic law results with equal height of surrounding obstructions is given in Figure 5. In this example all the points underestimate the measured infiltration rate and only four of the data points are within 25% of measurement. By taking an average of all the data points, the mean measured infiltration was 0.18 ach. This compared with a calculated value of 0.18 ach for simulation (i), 0.16 ach for simulation (ii), 0.14 ach for simulation (iii) and 0.12 ach for simulation (iv). The difference in shielding class had approximately a 10% influence on the power law results and a 12% affect on the quadratic results.

Discussion and Conclusions

It would be incorrect to completely rule out the quadratic approach since much also depends on the interpretation of flow path distribution, e.g. the validity of assuming a uniform distribution of air leakage openings, and on the assumptions used to derive the wind pressure field, i.e. shielding conditions and pressure coefficient values. With a sufficiently large database, the wind pressure problem could be eliminated by concentrating on stack driven (low wind speed) air infiltration conditions only. Although insufficient data was available for this exercise, a useful indication is presented in run number 14 (Table 1), where the building height wind speed is less than 1 m/s and the inside/outside temperature difference is 17.5°C. Under these conditions the wind effect is small. In the case of the power law, the infiltration prediction was an acceptable 0.08 ach for each shielding condition (compared with a measured value of 0.10 ach), while the quadratic formulation yielding a somewhat less acceptable 0.05 ach for each condition. Another possibility is that, in terms of steady state flow, the quadratic formulation is indeed correct but that the power law approach fortuitously compensates for the additional influence of turbulent fluctuations at low driving pressures.

Before any firm conclusions can be drawn it is necessary to consider a wider field of data but these preliminary results indicate that the power law approach is the most suitable method.

References

1. Etheridge, D.W.
   Crack flow equations and scale effect
   Building and Environment, Vol. 12, pp 181–189, 1977
2. Liddament, M.W. and Allen, C.
   The validation and comparison of mathematical models of air infiltration
   AIVC Technical Note No. 11, 1983
3. Liddament, M.W.
   Air infiltration calculation techniques – an applications guide
   AIVC, June 1986

Note: AIVC Technical Note 11 is now available to non-participating countries. Please see publications list in this Review for details.

Conference Report

BTECC Symposium on Air Infiltration, Ventilation and Moisture Transfer Washington DC, USA 2–4 December 1986

Report by Martin W. Liddament
Head, Air Infiltration and Ventilation Centre

This three day conference covered substantial ground in the area of ventilation and air quality in buildings. There were a total of eight sessions covering:

- analytical tools
- wall and fenestration moisture
- roof spaces moisture
- airtightness and air quality
- airtightness of commercial envelopes
- standards and technology transfer
- mechanical ventilation
- airtightness of residential envelopes

In all a total of 62 technical presentations were scheduled.

The analysis of ventilation related moisture problems was particularly in evidence and papers covered the numerical modelling of indoor humidity levels, the cyclical behaviour of moisture desorption/absorption by building and furnishing materials, the calculation of moisture balance in wood frame walls and an attic condensation-ventilation model. Andy Persily from the US National Bureau of Standards described the development of a knowledge based expert system which is under development to assist in the diagnosis of air leakage problems. The current prototype system is primarily concerned with moisture related problems and is the first step in the development of a more comprehensive expert system that will deal with many other air leakage problems such as indoor air quality, thermal comfort and heat loss/gain.

The expert system is being designed for use by home energy auditors who are familiar with house construction and building performance issues but do not have the experience and expertise necessary to deal effectively with the wide variety of circumstances encountered in houses. The system requires the user to characterise the symptoms of the existing moisture related problems and then requests additional information on pertinent house characteristics. In response to the user supplied data, a list of probable causes and recommendations for remedial action is produced.

In the session on moisture on walls and windows, Bill Jones from Ontario Hydro, Canada described laboratory condensation measurements on windows. He pointed out that thermally upgraded houses tended to operate at higher humidity levels as a consequence of increased airtightness. The most evident instance of this situation is extensive condensation on windows, normally the coldest interior surfaces in the dwelling. Damage to the sill and adjacent wall coverings, loss of transparency and of openability (if frozen shut) can result. A simple test facility was described to compare the condensation performance of various window types under winter conditions. This facility was used to compare a standard two-pane window (21mm airspace) with a low-emissivity (R-reflective) two-pane model. The relative extent of condenstion for the two windows was obtained for various outdoor temperatures and indoor humidity levels. Other tests were performed to show the effect of insect screens, wide window sills and outdoor wind conditions on the condensation performance.

Results show that the low emissivity window can withstand an 8% increase in relative humidity under normal winter conditions, or a 5°C decrease in outdoor temperature at the same humidity level. This is roughly consistent with the increased surface temperature measured. Wind significantly increased condensation, especially at low outdoor temperatures. Insect screens and wide sills (or insect windows) disturb air flow patterns over the window, increasing condensation somewhat. It was concluded that the ability of the low-emissivity window to tolerate higher indoor humidities, coupled with a lower heat loss and increased comfort (less radiative loss), makes such a window a significant improvement for modern construction.

In the session on airtightness and indoor air quality, Dr. J. Robertson of ACVA Atlantic Inc, discussed the source, nature and symptomology of indoor air pollutants. It was stated that the accumulation of indoor air pollutants inside many buildings has been seriously exacerbated by the current design and operating practices, primarily aimed at saving energy dollars. Two common denominators in many sick buildings are inadequate ventilation, specifically insufficient fresh air intake, and poor filtration. The latter is frequently a major contributor to a third common problem, namely the accumulation of dirt, dusts and microbes inside the air handling units and their associated ductwork.

Numerous case studies were illustrated showing how fibre optic technology could be used to examine the poor condition of ventilation systems. Other examples illustrated the misuse of fresh air dampers and the generally poor standard to which ventilation systems were maintained.

In the field of standards and technology transfer, both the progress and the application of standards were considered. During this session, Max Sherman from the Lawrence Berkeley Laboratory in California took the opportunity to present some of the background to the currently proposed ASHRAE Standard 119 on the air leakage performance of dwellings.

The session on mechanical ventilation covered a wide range of aspects including heat recovery, humidity control and the control of pressure differences. In a philosophical review of mechanical ventilation in the home, David Eyre of the Saskatchewan Research Council stated that North American houses have traditionally relied on 'natural ventilation' to replenish the indoor oxygen supply and remove indoor pollutants, including carbon dioxide and water vapour. However, 'natural ventilation' is really just a euphemism for 'air leakage'. Use of this euphemism disguises the fact that 'natural ventilation' is entirely unplanned and uncontrolled and, as a result, may be entirely inadequate in many houses. There is growing evidence that this is increasingly the case in the new housing being built in Canada. Recent studies have shown that, both by accident and by design, a major portion of our new housing is achieving levels of airtightness such that natural wind and convective pressures are unable to move sufficient air in and out of the house to maintain acceptable indoor air quality.

The question thus arises, 'Is the housing industry ready to install mechanical ventilation on a production basis?'. David went on to say that many familiar with the housing industry, and especially with the mechanical subcontracting portion of the industry, would answer 'No!'. However, the alternatives may be equally unpalatable and impractical. This suggests that there is an urgent need to upgrade the industry's capabilities in the area of mechanical ventilation.

The symposium ended with a wide ranging review of presentations. The full proceedings will be published by July 1987 by:

Building Thermal Envelope Co-ordinating Council
101 15th Street NW
Suite 700
Washington DC 20005, USA. Tel: 202 347 5710

How to Operate a Heat Recovery Ventilator R–2000 Super Energy Efficient Home Program

Energy, Mines and Resources Canada, 1986

The R–2000 Super Energy Efficient Home Program is a co-operative industry/government initiative sponsored by Energy, Mines and Resources Canada (EMR) and delivered by the Canadian Home Builders' Association (CHBA). Established in 1980, the program supports building industry development, product development and the training of builders to construct and market houses to the R–2000 energy performance target and technical requirements. These requirements encourage builders to treat the whole house as a system, incorporating the most appropriate combination of features.

The booklet is written primarily for occupants of R–2000 or equivalent homes. However, Heat Recovery Ventilators are also being installed in other types of homes including older houses that have been carefully 'airtightened'. Much of the information presented will be relevant and useful to many HRV user. The Heat Recovery Ventilators can help ensure a healthy, clean and comfortable home environment without the penalty of high fuel bills. The booklet is designed to help users to achieve the full benefits. It explains how it works, how to operate it, possible problems and solutions, and routine maintenance requirements.

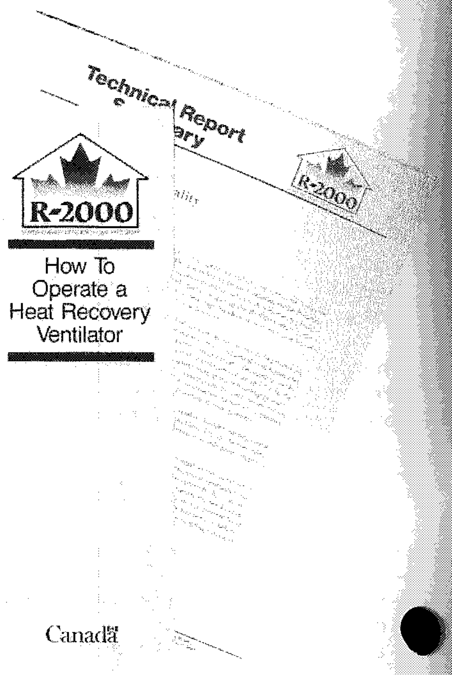
Ventilation and Air Quality in R–2000 Homes Technical Report Summary

Energy, Mines and Resources Canada, 1986

The second leaflet is a technical report summary describing the R–2000 Home Monitoring Program. It includes sections on monitoring procedures, the ventilation system, air change rates, and on formaldehyde, radon and nitrogen dioxide as specific examples of pollutants being monitored. The R–2000 Home Program stresses superior indoor air quality and every R–2000 home is equipped with a mechanical ventilation system to ensure an adequate supply of fresh air. The ventilation requirements recognise the need to provide both continuous ventilation for normal conditions and additional ventilation on an intermittent basis to control excessive humidity and odour when the need arises. The system must also be balanced – neither creating nor contributing to an overall positive or negative pressure difference in the building envelope relative to the exterior.

Information on further booklets and publications can be obtained from:

Energy, Mines and Resources Canada
R-2000 Program
580 Booth Street
Ottawa, K1A OE4
Canada
Tel: (613) 995 1118



Natural Ventilation in Large and Multicelled Buildings – Theory, Measurement and Prediction EEC: Energy Report EUR 10552 EN, 1986

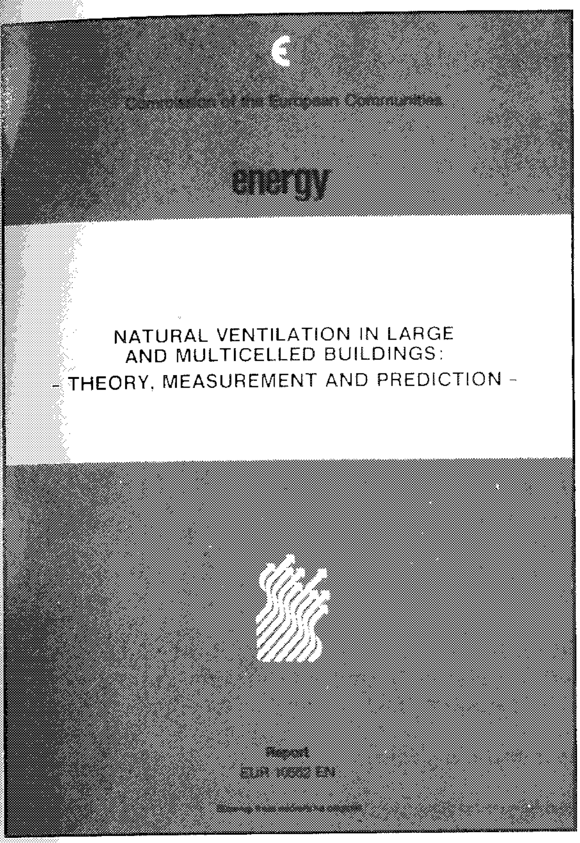
M.D.A.E.S. Perera, R.R. Walker, M.B. Holloway, O.D. Oglesby and P.R. Warren
Building Research Establishment, Watford, UK

This is the final report of a study conducted between 1st October 1981 and 30th June 1984. The overall objective of the research was to broaden the area of knowledge of natural ventilation to include types of building other than dwellings. In particular, large and more complex, e.g. multicellular, buildings such as offices.

A combination of theoretical and experimental studies was used to establish methodologies for determining infiltration rates of large and complex buildings. Theoretical considerations suggested that comprehensive information regarding interzonal air movements might be obtained from experimental techniques using multiple tracer gases. Field measurements to determine interzonal flows were carried out in office buildings using automated measurement systems developed for this purpose.

It was recognised that, in most circumstances, simpler techniques were needed which would give less comprehensive but nevertheless useful information. Such a simplified technique has been developed. Theoretical and experimental work showed that, with this technique, it is probably sufficient to seed part of the complex building with a single tracer gas in order to measure the overall infiltration rate to a good approximation.

Prediction models have also been used to determine the effectiveness of draughtproofing windows on the energy consumption of an office building. The predicted infiltration rates compared well with measured values. Energy calculations showed that, for this particlar building, draughtproofing windows has reduced the seasonal gas consumption by 21%.



The report's ten sections are:

- Introduction
- Theoretical basis for measuring ventilation rates in multicelled buildings
- Review of experimental techniques
- Development of automated systems to measure airflows
- Field measurements using automated systems
- Field development of simplified strategies for ventilation measurement in office buildings
- Strategy for measuring infiltration rates in naturally ventilated multicelled buildings using a single tracer gas
- Evaluation of simplified equipment and techniques of tracer sampling
- Effect of draughtproofing windows on the energy consumption of an office building
- Final conclusions.

Further information from:
Building Research Establishment, Building Research Station, Garston, Watford, Herts WD2 7JR, England. Tel: 0923 674040

Technical Notes Now Available to Organisations in Non-Participating Countries

The following AIVC Technical Notes are now available in all countries:

AIC-TN-10-83 – Liddament, M., Thompson, C.
'Techniques and instrumentation for the measurement of air infiltration in buildings – a brief review and annotated bibliography'
(Price £15 to non-participating countries)

AIC-TN-11-83 – Liddament, M., Allen C.
'The validation and comparison of mathematical models of air infiltration'
(Price £15 to non-participating countries)

AIC-TN-13-84 – Allen, C.
'Wind pressure data requirements for air infiltration calculation'

AIC-TN-13.1.-84
'1984 Wind pressure workshop proceedings'
(Supplied as a two-volume set, price £20 to non-participating countries)

Full details of these technical notes are given in the publications list on page 10 and they may be obtained by completing the order form on page 11 and sending the appropriate remittance to:

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Forthcoming Conferences

1. FAC '87
'Future air conditioning'
London, UK
24 – 25 February 1987

Further details from:

CIBSE
222 Balham High Road
London SW12 9BS
UK
Tel: 01-675 5211

2. AIRAH 1987 Federal Conference
'Ventilate a fresh idea'
Brisbane, Australia
6 – 10 April 1987

Technical sessions to be staged at the Bardon Professional Centre

Further details from:

John Bosci
c/- Lincolne Scott Aust Pty Ltd
88 Jephson Street
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Qld 4066
Australia
Tel: (07) 371 8811
Telex: AA 444 77
Fax: (07) 870 1022

or

Ross Devereux
PO Box 37
Indoorphilly
Qld 4068
Australia
Tel: (07) 8921100

3. 1987 European Conference on Architecture
European Patent Office
Munich
Federal Republic of Germany
6 – 10 April 1987

Further details from:

H.S. Stephens and Associates
Conference Organisers
Agriculture House
55 Goldington Road
Bedford MK40 3LS
England
Tel: +442344 9474
Telex: 82392 Robins G.

4. 'Energy options: The role of alternatives in the world energy scene'
Reading, UK
7 – 9 April 1987

Further details from:

Conference Secretariat
Institution of Electrical Engineers
Savoy Place
London WC2R OBL
Tel: 01-240 1871 x222
Telex: 261176 IEE LDNG

5. IHVEX '87
Dublin, Republic of Ireland
14 – 16 April 1987

Further details from:

Irish Trade and Technical Exhibitions Ltd
5-7 Main Street
Blackrock
Co Dublin
Republic of Ireland
Tel: 0001 88501

6. International Energy Exhibition
Budapest, Hungary
14 – 17 April 1987

Further details from:

Hungexpo
Dobi Istvan Ut
10, PO Box 44
1441 Budapest
Hungary
Tel: (01) 573 555

7. ASHRAE Annual Meeting 1987
Opryland Hotel, Nashville, Tennessee, USA
28 June – 1 July 1987

Further details from:

Judy Marshall
ASHRAE
1791 Tullie Circle N E
Atlanta
GA 30329
USA

8. Indoor Air '87
Berlin, Federal Republic of Germany
17 – 21 August 1987

Further details from:

Conference Secretariat
Indoor Air '87
c/o CPO Hanser Service GmbH
Schaumburgalee 12
D-1000 Berlin 19
Federal Republic of Germany
Tel: (030) 305 31 31
Telex: 186 11 cpo d

9. 8th AIVC Conference
Ventilation technology research and application
Überlingen, Federal Republic of Germany
21 – 24 September 1987

Further details from:

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Air Infiltration and Ventilation Centre
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Bracknell
Berkshire RG12 4AH
Great Britain

Tel: +44 344 53123
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10. Healthy Buildings '88
CIB Conference in Stockholm, Sweden
5 – 8 September 1988

Further details from:

CIB/Healthy Buildings '88
c/o Stockholm Convention Bureau
PO Box 6911
S-10239 Stockholm
Sweden

AIVC Publications List

PERIODICALS

Air Infiltration Review
Quarterly newsletter containing topical and informative articles on air infiltration research and application. Also gives details of forthcoming conferences, recent acquisitions to *AIRBASE* and new AIVC publications. *Unrestricted availability, free-of-charge.*

Recent Additions to *AIRBASE*
Quarterly bulletin of abstracts added to *AIRBASE*, AIVC's bibliographic database. Provides an effective means of keeping up-to-date with published material on air infiltration and associated subjects. Copies of papers abstracted in 'Recent Additions to *AIRBASE*' can be obtained from AIVC library. *Bulletin and copies of papers available free-of-charge to participating countries* only.*

GUIDES AND HANDBOOKS

AIC-AG-1-86 – Liddament, M.W.
'Air Infiltration Calculation Techniques – An Applications Guide'
A loose-leaf handbook divided into six chapters covering empirical and theoretical calculation techniques, algorithms, references and glossary of terms. *Available free-of-charge to participating countries* only, via your national Steering Group representative.*

HANDBOOK – Elmroth, A., Levin, P.
'Air infiltration control in housing. A guide to international practice'
An international guide to airtightness design solutions of great practical value to all those concerned with the design of pollution – free dwellings with low energy demands. *Unrestricted availability. Price £12.50 hard copy. Also available in microfiche £10.00.*

TECHNICAL NOTES

AIC-TN-5-81 – Allen, C.
'AIRGLOSS: Air Infiltration Glossary (English edition)'
Contains approximately 750 terms and their definitions related to air infiltration, its description, detection, measurement, modelling and prevention as well as to the environment and relevant physical processes. *Available free-of-charge to participating countries.* Price: £10 to non-participating countries.*

AIC-TN-5.1-83 – Allen, C.
'AIRGLOSS: Air Infiltration Glossary (English-German/Deutsch-Englisch) Supplement'
Available free-of-charge to participating countries. Price £7.50 to non-participating countries.*

AIC-TN-5.2-84 – Allen, C.
'AIRGLOSS: Air Infiltration Glossary (English – French/Français – Anglais) Supplement'
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AIC-TN-5.3-84
'AIRGLOSS: Air Infiltration Glossary (Italian Edition)'
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AIC-TN-6-81 – Allen, C.
'Reporting format for the measurement of air infiltration in buildings'
Produced to provide a common method for research workers to set out experimental data, so assisting abstraction for subsequent analysis or mathematical model development. May be used directly for entering results and as a useful checklist for those initiating projects. Example of use of format is included as an appendix. *Available free-of-charge to participating countries.* Price: £6 to non-participating countries.*

AIC-TN-10-83 – Liddament, M., Thompson, C.
'Techniques and instrumentation for the measurement of air infiltration in buildings – a brief review and annotated bibliography'
Four-section bibliography contains review papers, information on tracer gas techniques, pressurization methods and miscellaneous approaches. In addition the report contains a list of manufacturers of instrumentation currently being used in air infiltration investigations. *Available free-of-charge to participating countries.* Price: £15.00 to non-participating countries.*

AIC-TN-11-83 – Liddament, M., Allen, C.
'The validation and comparison of mathematical models of air infiltration'
Contains analysis of ten models developed in five participating countries. These range in complexity from 'single-cell' to 'multi-cell' approaches. Also contains numerical and climatic data for fourteen dwellings compiled to produce three key datasets which were used in model validation study. *Available free-of-charge to participating countries.* Price: £15.00 to non-participating countries.*

AIC-TN-12-83 – Liddament, M.
Superseded by TN19 (see below).

AIC-TN-13-84 – Allen, C.
'Wind Pressure Data Requirements for Air Infiltration Calculations'
An up-to-date review of the problems associated with satisfying the wind pressure data requirements of air infiltration models. *Available free-of-charge to participating countries.* Price: £20.00 (price includes copy of TN-13.1) to non-participating countries.*

AIC-TN-13.1-84
'1984 Wind Pressure Workshop Proceedings'
Report of written contributions and discussion at Workshop held in March 1984, Brussels. *Available free-of-charge to participating countries.* Also available to non-participating countries (see note at TN-13 above).*

AIC-TN-14-84 – Thompson, C.
'A Review of Building Airtightness and Ventilation Standards'
Lists and summarises airtightness and related standards to achieve energy efficient ventilation. *Available free-of-charge to participating countries* only.*

AIC-TN-16-85 – Allen, C.
'Leakage Distribution in Buildings'
Examines those factors which can influence leakage distribution, including building style, construction quality, materials, ageing, pressure and variations in humidity. *Available free-of-charge to participating countries* only.*

AIC-TN-17-85 – Parfitt, Y.
'Ventilation Strategy – A Selected Bibliography'
Review of literature on choice of ventilation strategy for residential, industrial and other buildings. *Available free-of-charge to participating countries* only.*

AIC-TN-18-86 – Parfitt, Y.
'A subject analysis of the AIC's bibliographic database – *AIRBASE*.' 4th Edition
Comprehensive register of published information on air infiltration and associated subjects. The articles are indexed by subject and full bibliographic details of the 2,000 papers are given. A list of principal authors is also included. *Available free-of-charge to participating countries* only.*

AIC-TN-19-86 – Charlesworth, P.
'1986 Survey of current research into air infiltration and related air quality problems in buildings'
Fourth worldwide survey by AIVC containing over 200 replies from 19 countries. Produced in two sections: an analysis in tabular form of survey results, followed by reproduction in full of research summaries and list of names and addresses of principal researchers. *Available free-of-charge to particpating countries* only.*

LITERATURE LISTS – Listing of abstracts in *AIRBASE* on particular topics related to air infiltration.

No. 1 Pressurization – Infiltration Correlation: 1. Models (17 references).
No. 2 Pressurization – Infiltration Correlation: 2. Measurements (26 references).
No. 3 Weatherstripping windows and doors (24 references).
No. 4 Caulks and sealants (24 references).
No. 5 Domestic air-to-air heat exchangers (25 references).
No. 6 Air infiltration in industrial buildings (42 references).
No. 7 Air flow through building entrances (22 references).
No. 8 Air infiltration in commercial buildings (28 references).
No. 9 Air infiltration in public buildings (10 references).
No. 10 CO_2 controlled ventilation (13 references).
No. 11 Occupancy effects on air infiltration (15 references).
No. 12 Windbreaks and shelter belts (19 references).
No. 13 Air infiltration measurement techniques (27 references).
No. 14 Roofs and attics (34 references).
No. 15 Identification of air leakage paths (23 references).

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CONFERENCE PROCEEDINGS

No. 1 'Instrumentation and measuring techniques'.
Unrestricted availability. £35.00 sterling.
No. 2 'Building design for minimum air infiltration'.
Unrestricted availability. Price: £15.00 sterling.
No. 3 'Energy efficient domestic ventilation systems for achieving acceptable indoor air quality'.
Unrestricted availability. Price: £23.50 sterling.
No. 4 'Air infiltration reduction in existing buildings'.
Unrestricted availability. Price: £16.00 sterling.
No. 5 'The implementation and effectiveness of air infiltration standards in buildings'.
Unrestricted availability. Price: £22.00 sterling.
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Unrestricted availability. Price: £16.00 sterling.
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