Air Infiltration Review

a quarterly newsletter from the IEA Air Infiltration and Ventilation Centre

Vol. 8, No. 1, November 1986

The Air Infiltration and Ventilation Centre

Following the Centre's change of name, the full complement of AIVC staff has now been appointed. Staff of the Centre are:

Back row (left to right):
Steve Irving (Operating Agent, Oscar Faber Consulting Engineers), Peter Charlesworth (Scientist), Peter Jackman (Programme Advisor), Martin Liddament (Head of Centre).

Front row (left to right):
Emma Young (Clerical Assistant), Janet Blacknell (Information Specialist), Jenny Elmer (Secretary).

Please do not hesitate to contact us if you require advice, assistance or literature in the field of air infiltration and ventilation research.

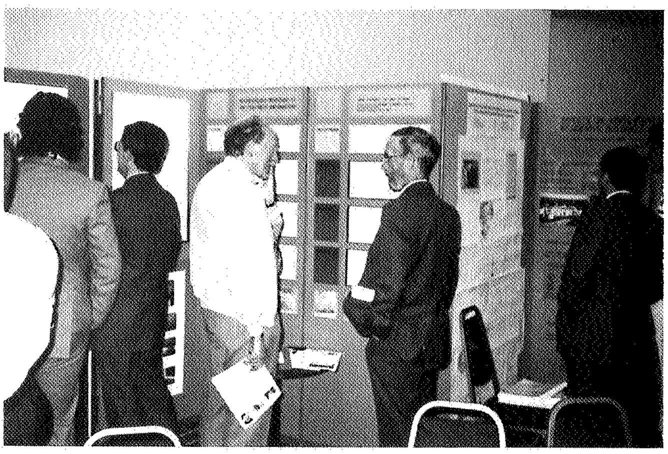
Inside this issue:

AIVC Conference Report

Stratford Conference Attracts Participants from 13 Countries

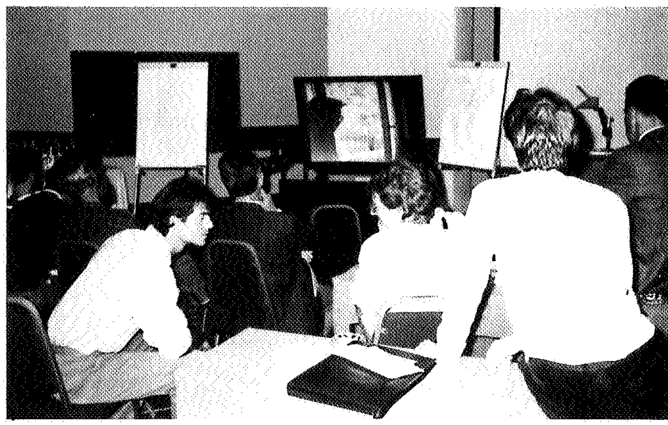
The AIVC's 7th Annual Conference held in Stratford-upon Avon, UK, attracted over 70 participants from 13 countries. A special welcome was extended to guest speakers from France and Hungary and to representatives of IEA Annex VIII on occupancy interaction. The theme of the conference was 'Occupant Interaction with Ventilation Systems'.

In the keynote address, Roger Courtney (Deputy Director of the UK Building Research Establishment) put the energy consequences of air infiltration into perspective. The theme of his address was to set an energy efficiency context for research into air infiltration, to summarise current research themes and to suggest aims for research into air infiltration and occupant behaviour. It was pointed out that, as the thermal performance of the building envelope increased, ventilation heat loss became more significant. On the other hand it was recognised that ventilation was essential and that there was still uncertainty on the minimum level of acceptable ventilation. The role of the fan pressurization test was quoted as a good indicator of whether natural infiltration (the common UK approach to ventilation in dwellings) would normally be inadequate, excessive or satisfactory. It was regarded that a generally acceptable value for air leakage at an applied pressure of 50 Pa would be in the range of 10–20 airchanges/hour (with doors and windows closed and flues sealed). Nationally it was estimated that some 30–40% of the present stock of UK dwellings would benefit from reduced infiltration rates with a national annual primary energy saving of about 40 PJ. Assuming a similar saving in non-domestic buildings, the resultant savings in financial terms could be as much as £200 million annually.



AIVC's first poster session.

It was concluded that at the moment it is not realistic to include requirements on ventilation rates in UK Building Regulations. This is because it could not be specified with sufficient confidence nor could conformance be monitored. However, non-statutory documents should certainly include guidance on the control of infiltration. Thus advisory material and professional codes should be used to promote good practice in control of infiltration.



Conference delegates view the video 'Fenêtres et Radiateurs, une Adventure au Quotidien' – Windows and Radiators, a Daily Adventure – directed by Yves Pedrazzini (foreground, lefthand side).

Following on from the keynote paper, Lutz Trepte of Dornier Systems in West Germany discussed requirements for adequate ventilation and user acceptable ventilation. He concluded that occupant comfort and acceptance has so far not found appropriate consideration with the design of ventilation systems of any kind. Real progress depended on such factors as ventilation effectiveness, an integrated approach to pollution removal, energy conservation and comfort, improved natural ventilation methods and retrofit ability being given much more emphasis.

Other contributions were of a more specific nature, often concentrating on detailed case studies. Dominique Bienfait from the Centre Scientifique et Technique du Batiment in France described the results of a survey on inhabitant behaviour with regard to mechanical ventilation in France. The results showed that actual ventilation rates frequently differed from prescribed values and that many of the encountered problems were related to occupant behaviour. Particular problems occurred through draughts through air inlets and the failure of many vents to operate correctly as a result of fouling. Ake Blomsterberg from the Swedish National Testing Institute also reported on user controlled exhaust ventilation. A set of 18 single family dwellings was monitored, each fitted with a 3-way fan speed control which could be set according to the level of occupancy.

Bjørn Kvisgaard from Bruel and Kjaer reported on tracer gas measurements made for a period of one week in both mechanically ventilated and naturally ventilated occupied dwellings. He showed that occupancy patterns had a considerable influence on the total air change rate. In the naturally ventilated homes, users, on average, accounted for over 60% of the total air change while in mechanically ventilated homes user influence was again considerable.

Demonstration of AIRBASE by Janet Blacknell, AIVC librarian

The IEA Annex VIII session highlighted the co-operative research programme of Belgium, the Netherlands, West Germany, Switzerland and the United Kingdom on inhabitants' use of ventilation. The effects of window opening, the influence of climate and sociological patterns were covered as were indoor climate, comfort and moisture control. Other papers from the United States, Hungary and Finland also dwelt on these topics.

For the first time, the Centre held an evening poster session which was exceptionally well attended. The poster presentations were to a very high standard and included a video presentation by Yves Pedrazzini from the Federal Institute of Technology, Lausanne, Switzerland, and a computer demonstration of AIRBASE by the AIVC's new information specialist, Janet Blacknell.

There was also a well-attended visit to the Milton Keynes Energy Park where visitors had the opportunity to investigate modern trends in UK housing.

Full proceedings of the Conference will be available shortly at a price of £25 sterling.

Announcing the AIVC's 8th Annual Conference

CALL FOR PAPERS

The date of the Centre's next conference is 21 – 24 September 1987 and the theme is Ventilation Technology Research and Application. Papers covering the following key areas are required.

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

Abstracts not exceeding 200 words of proposed papers on the above topics are welcome and should be received by the AIVC no later than 31 January 1987. The abstracts will be subjected to review in March 1987 and print-ready copies of accepted papers will be required by July 1987. Submissions from the non-AIVC participating countries are welcome and, if the abstracts are accepted, the authors will be invited to participate in the conference.

The conference format will take the form of both author presentations and poster sessions – therefore interested authors should state their preference.

Programme and registration details will be published in the May 1987 edition of AIR. Booking forms will be obtainable from your Steering Group representative. Meanwhile, please reserve the Conference dates 21–24 September 1987 in your diary.

The conference venue is yet to be confirmed, but is most likely to be in West Germany.

New Staff at the AIVC

Janet Blacknell joined the staff of the Air Infiltration and Ventilation Centre on 11 August 1986. She graduated in English and French at the University of Leeds in 1983 and has just completed a postgraduate course in librarianship at the College of Librarianship Wales, Aberystwyth, following a period of pre-library school training at the Department of Education and Science in London. She is fluent in French, German and Portuguese and is currently responsible for operating and up-dating the AIVC's bibliographical database, AIRBASE, and maintaining the AIVC's collection of information on air infiltration and related subjects.

The Determination of Leakages by Simultaneous Use of Tracer Gas and Pressurization Equipment

P. Wouters, D. l'Heureux, P. Voordecker
Belgian Building Research Institute

Introduction

The air leakage distribution in a building is, in certain circumstances, difficult to determine. One example of this is the ceiling of the dwelling illustrated in figure 1 and 2. It is almost impossible to make the ceiling perfectly airtight; this means that a measurement by difference is impossible. The inclined roof is not airtight at all. A rather simple and easy technique is to perform measurements using tracer gas and pressurisation equipment at the same time.

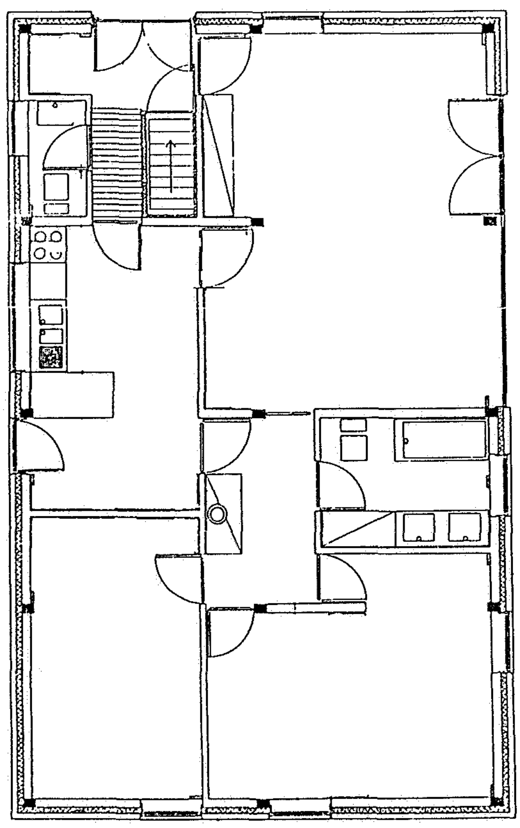


Figure 1. Plan view of test house.

Principle of the measurement

The essential characteristics of the measurements are:

1. A more or less constant concentration of tracer gas in the attic. This can be done by using constant concentration equipment or by using the constant injection technique if the weather conditions are stable.
2. The rest of the house is under depressurisation, for example $\Delta P_{ie} = 50$ Pa.
3. The measurement of the gas concentration in the attic and at the entrance of the pressurisation door:

   $CONC_D$ = concentration in the dwelling

   $CONC_A$ = concentration in the attic.

It is clear that the gas measured in the house is coming through the leakages in the ceiling.

Therefore:

$$\frac{\text{effective leakage area in the dwelling } (ELA_D)}{\text{effective leakage area in the ceiling } (ELA_A)} = \frac{CONC_D}{CONC_A}$$

ELA_D can be obtained from a global pressurisation measurement, so that:

$$ELA_A = ELA_D \times \frac{CONC_D}{CONC_A}$$

It is evident that this relation is theoretically only valid for the ΔP_{ie} used during the measurement. The results are only valid if a good mixing of the tracer gas in the attic can be obtained.

The principle is based on steady-state conditions. One can show that these are almost fulfilled after 2/n hours (n = air change rate during the pressurisation test).

This means that for a dwelling with a n_{50}-value of 5 h^{-1} the measurements can be started after 2 x 1/5 hour or 24 minutes if $\Delta P_{ie} = 50$ Pa. In this case of very airtight houses, a non-steady state analysis may be necessary.

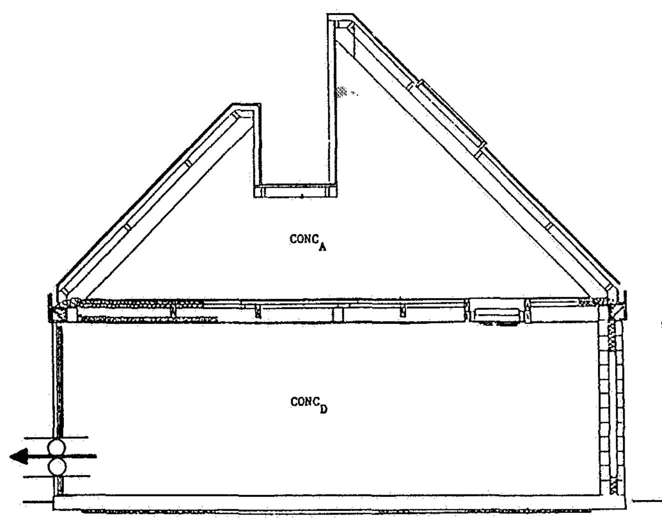


Figure 2. End elevation of test house.

Example

Table 1 shows results obtained in two identical houses at the Belgian Building Research Institute.

	% of leakages	
	Ceiling	Floor above cellar
Dwelling 1	16	22
Dwelling 2	28	17

Table 1 – The total percentage leakage area in the attic and the cellar ($n_{50} \simeq 10\ h^{-1}$).

AIVC Measurement Techniques Handbook

Peter Charlesworth, AIVC Scientist

The measurement of building air infiltration rate dates back to the 1930's. Since that time a great number of measurement techniques (for the evaluation of air infiltration, room-to-room air movement, air leakage, etc.) have been developed, tested and refined. In recent years, with the advent of micro-computers, measurement methods have become more sophisticated – often allowing measurements to be taken over several days without human supervision.

Despite the increase in use and number of numerical methods for evaluating air infiltration, etc., practical measurements performed in real buildings are still of vital importance. These measurements enable computer models to be validated and act as further input for the refinement of these models. They also allow for the immediate on-site assessment of new building techniques, ventilation strategies and retrofit measures.

The AIVC recognises the following three points.

1. The continuing importance of full scale measurements of such parameters as air infiltration, air leakage, etc.

2. The lack of a comprehensive review and explanation of the various techniques which are available for the measurement of these parameters.

3. The bewildering variety of techniques which now face any researcher contemplating work in this area.

Hence the future work programme of the AIVC includes the production of a Measurement Techniques Handbook. The function of the handbook is to

a) provide a directory of the measurement techniques currently in use, including an explanation of their theoretical basis and practical applications.

b) provide a guide for researchers to enable them to choose the most appropriate technique for the parameter they wish to measure.

In order to fulfil these two roles, the Measurement Techniques Handbook will have the following structure.

The general presentation of the handbook will follow a similar format to the recently published AIVC Calculation Techniques Guide. This will enable information about newly developed measurement techniques to be added to the handbook if required.

Introduction

– Role of full scale measurements in air infiltration and related studies

– Scope of handbook

– How to use handbook

Summary of Techniques (Theory and Evaluation)

– Tracer gas methods

decay rate
constant concentration
constant emission
passive techniques
multi-tracer techniques

– Pressurization

d – c methods
a – c methods

– Other techniques

thermography
flow visualisation
acoustic leak detection

Building Types/Selecting a Technique

– Cross reference building type (single cell, multi-cell, domestic, industrial, etc.) with most appropriate measurement technique for a particular parameter, e.g. air change rate, pressure distribution, etc.

Case Studies

– This section will be based on the replies received to a detailed questionnaire which will be sent to researchers who are using the various techniques under examination.

Instrumentation

– This section will cover the instrumentation used to measure the various parameters (gas concentration, pressure difference, temperature, flow rate, etc.) which are evaluated when using each type of measurement technique. It will be compiled from the information given in the returned questionnaires and from manufacturers' product manuals.

Contacting the AIVC

24 hour telex/telephone service

To avoid postal delays, requests for literature or AIVC publications may be made at any time of day or night via the AIVC telex or telephone answering service. *AIRBASE* literature may be ordered simply by quoting the reference number.

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Air Infiltration and Ventilation Calculation Techniques

M.W. Liddament, Head of AIVC

Introduction

A range of calculation techniques is available for the calculation of air infiltration and ventilation in buildings. The choice is largely dependent on intended application, while the level of complexity ranges from straightforward empirical techniques to detailed multi-zone numerical methods. The objective of this article is to outline some of the techniques currently available and to indicate the purposes for which they are most suited. More detailed information is presented in the AIVC's Air Infiltration Calculation Techniques Guide.[1] The prime function of these techniques if to provide basic data for ventilation design and associated parameters (Figure 1).

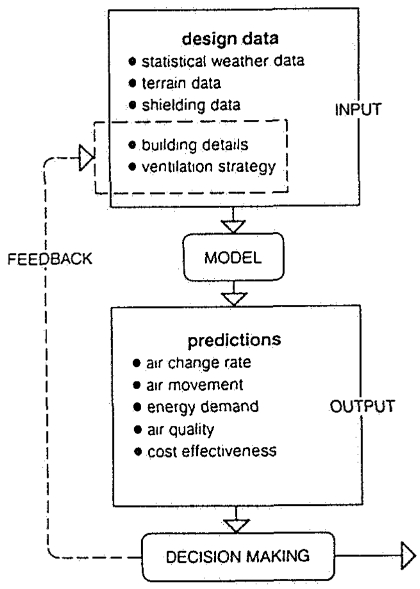

Figure 1: Role of mathematical modelling in design

Calculation techniques

In practice, the choice of calculation technique varies according to the required level of accuracy, the availability of data and the type of building under investigation. Consequently, a wide variety of methods have been developed to cope with the problems of estimating the rates of air infiltration in buildings, with no single method being universally appropriate.

Despite the many methods, prediction techniques can be grouped into five generic forms. These are:

(i) 'air change' methods.

(ii) 'reduction' of pressurization test data.

(iii) regression methods.

(iv) theoretical flow network models.

(v) 'simplified' theoretical techniques.

Methods (i) - (iii) are essentially empirical techniques in which the calculation of air infiltration is only loosely based on the theoretical principles of air flow. While these methods tend to be fairly straightforward to apply, they usually have a rather limited range of applicability. The remaining methods are based on a much more fundamental approach involving the solution of the equations of flow for air movement through openings in the fabric of the building. These methods have a potentially unrestricted range of applicability but can be very demanding in terms of computer execution time and data needs. The final choice of method is largely dependent on the intended application for which the air infiltration prediction is required. It should also be noted that the various forms of calculation technique have a hierarchical order representing both their range of applicability and their level of complexity (Figure 2). As a general rule, alternative methods for specific applications can only be selected by moving up the hierarchy. In the following, a brief description of these methods and the applications appropriate to each technique are outlined.

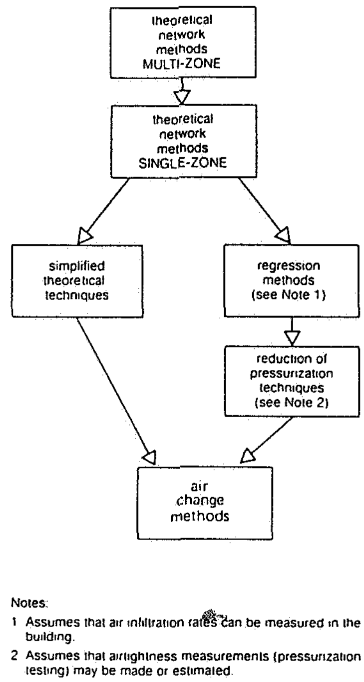

Figure 2: Hierarchical order of techniques

Air change methods

These are the 'classical' methods to be found in Section A4 of the CIBSE Guide (2) and in Chapter 22 of the ASHRAE Fundamentals (3) for the sizing of heating appliances. The purpose of this approach is to estimate an air change rate for specific design conditions for use in estimating the total heating or cooling load on the system. For such a task, intricate detail of the flow process is not required; instead the utmost simplicity is sought.

Reduction of pressurization test data

This is a very simple technique which nevertheless provides valuable information concerning the average infiltration performance of a building. The artificial pressurization or depressurization of a building as a means of assessing air leakage performance is now a fairly common practice (4). In itself it can only provide data regarding the 'leakiness' of the building (usually expressed in terms of air change rate at a 50 Pa pressure difference, Q_{50}). The result provides no information on the distribution of openings or shielding. However, numerous experimental tests have shown that the approximate mean air infiltration rate will be of the order of one twentieth of the measured air change rate at 50 Pa, ie:

$$\text{Infiltration} = Q_{50}/20$$

This provides a useful 'rule of thumb' estimate should pressurization test data be available. It is of value when considering the implications of building airtightness on the design performance of either natural or mechanical ventilation strategies. For example, a naturally ventilated building intended to meet an average ventilation requirement of 0.5 air changes per hour (ach) would require an overall air leakage rate at 50 Pa of not less than 10 ach. Similarly a mechanically ventilated building would need a considerably greater degree of airtightness if interference by air infiltration is to be avoided. This method is only suitable for small buildings such as dwellings, in which the pressurization test can be made.

Regression techniques

This method is based on the results of statistical fits to long-term time series data of infiltration rate measurements and associated climatic data. In its most basic form, air infiltration is expressed as a linear function of wind and temperature, ie:

$$I = A + B\Delta T + CV \qquad (1)$$

where, A, B and C are regression coefficients

ΔT = internal/external temperature difference

V = wind speed

Known combinations of ΔT and V are substituted into the above equation and the regression coefficients are calculated by the method of least squares.

The main value of this approach is in the extrapolation of results beyond a measurement period. Typically, hourly rates of air infiltration are continuously measured over a period of a few days. Appropriate regression coefficients are then evaluated and the performance of the infiltration equation is verified over a further short measurement period. The regression equation may then be used to estimate the air infiltration performance of the building over a wider set of climatic conditions.

The main disadvantage of this method is that the calculated regression coefficients are unique to the building since they reflect not only the airtightness performance of the building but also its orientation with respect to adjacent obstructions. It is therefore not possible to transfer the data to other buildings. Although representative values of regression coefficients have been published for design purposes, they can be very unreliable.

Theoretical network models

The severe limitations imposed by the preceeding techniques render them unsuitable for detailed design calculations. Instead, consideration must be given to a theoretical analysis of the problem. Such methods take the form of a flow network in which nodes representing regions of differing pressure are interconnected by leakage paths. This network is described by a set of simultaneous equations formed by applying an appropriate flow equation to each path. These equations are then solved by determining an internal pressure distribution such that a mass flow balance is preserved between the infiltrating and exfiltrating air masses.

Theoretical models of varying degrees of complexity are available and it is important therefore to make the correct selection according to both building type and intended application. The simplest of all network models approximates the interior of a building as a single zone at uniform pressure. This approximation is generally satisfactory for industrial type buildings such as factories and warehouses and for calculating the overall air change rate in dwellings. However, where partitioning presents an impedence to the general movement of air, it is necessary to divide the interior of the buildings into discrete zones with interconnecting flow paths. Such an approach is almost always necessary in commercial and multi-storey buildings in which floor space is partitioned into office accommodation or in which individual floors are connected by lift shafts and stairways, etc.

Simplified theoretical techniques

A number of 'simplified' methods have been introduced in an effort to minimise the computational effort of theoretical techniques yet enable some of the accuracy of these methods to be retained. As yet they are only applicable to single zone structures and only provide estimates of infiltration. They give no indication of the pattern of air distribution. Two such methods have been analysed by the Air Infiltration and Ventilation Centre and have been found to give satisfactory results for a range of dwellings and climatic conditions (6). These methods have been developed by the Building Research Establishment in the United Kingdom (BRE model) (7) and the Lawrence Berkeley Laboratory in the United States (LBL Model) (8).

Algorithms

Algorithms dealing with empirical type calculation methods may be readily located in the CIBSE Guide (2) and ASHRAE Fundamentals (3). No computing requirements are necessary and it should be possible to perform these calculations with ease. In contrast, the algorithms used to solve network problems are necessarily much more demanding and computing resources are essential. Many of the early methods required main-frame computing facilities and were therefore not generally available. Network type algorithms are available on a commercial or consulting basis from several organisations specialising in building services software. There are also a small number of published routines that can be adapted to suit individual needs. One such algorithm has been published by the National Bureau of Standards in the United States (9). This is a comprehensive multi-zone technique published in FORTRAN IV. It has been used to analyse air infiltration and inter-room air flow rates in commercial buildings. More recently this algorithm has been successfully run on an IBM-AT micro computer for flow networks of up to seven zones for a total of 37 flow paths (10). A multi-zone network model for operating on an IBM PC has also been developed by the Building Research Establishment (11) in the United Kingdom. The increasing availability of network models for the small computer is an important advance and will hopefully lead to the wide use of multi-zone methods in the design of energy efficient ventilation techniques.

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Full details from:

Air Infiltration Calculation Techniques – An Applications Guide. Copies available (to organisations in participating countries only – see back cover for details), direct from your Steering Group Representative only.

Book Reviews

Ventilation '85

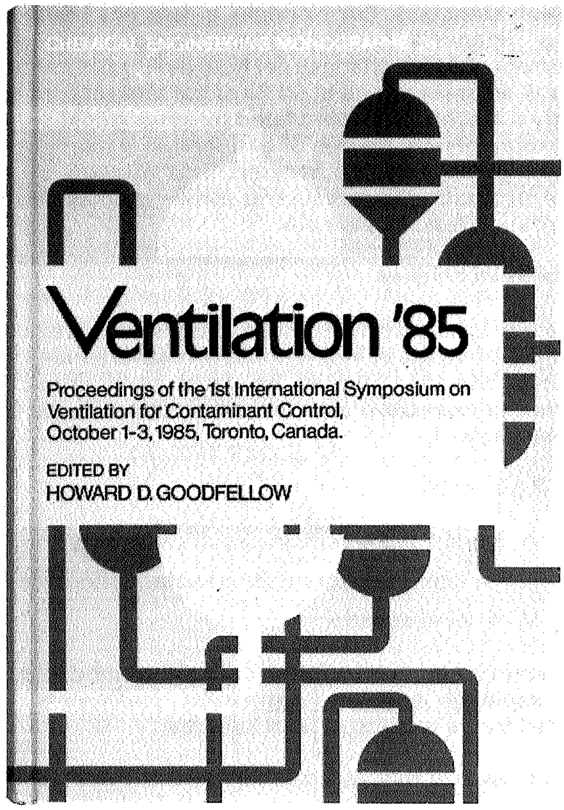
Proceedings of 1st International Symposium for Contaminant Control, Toronto, Canada. 1 – 3 October 1985. Editor: H.D. Goodfellow (In series Chemical Engineering Monographs, 24)

The focus of this international symposium was on recent developments and significant technological advancements in the ventilation field world-wide. The book contains the 68 papers presented, including the plenary session papers by invited speakers who are recognized world authorities in specific types of ventilation for contaminant control. Research data and design equations for the ventilation field are presented for the first time.

The 12 technical sessions, lasting for the three days of the conference are as follows:

- Advanced developments in ventilation.
- Control of toxic and explosive contaminants.
- Advances in tracer gas use – I, II.
- Ventilation for residential and modern office buildings.
- Advances in local exhaust technology – I, II, III.
- Ventilation for control of carcinogens and biohazards.
- Ventilation measurement and control.
- Source emission rates.
- Filters, air recirculation and energy conservation.

Within these sessions over 70 technical papers were presented.



Available from: Elsevier Science Publishers, PO Box 211, 1000 AE Amsterdam, Netherlands US$ 183.25/Dfl 495.00. ISBN 0-444-42622-1 (Vol. 24) ISBN 0-444-41295-6 (series).

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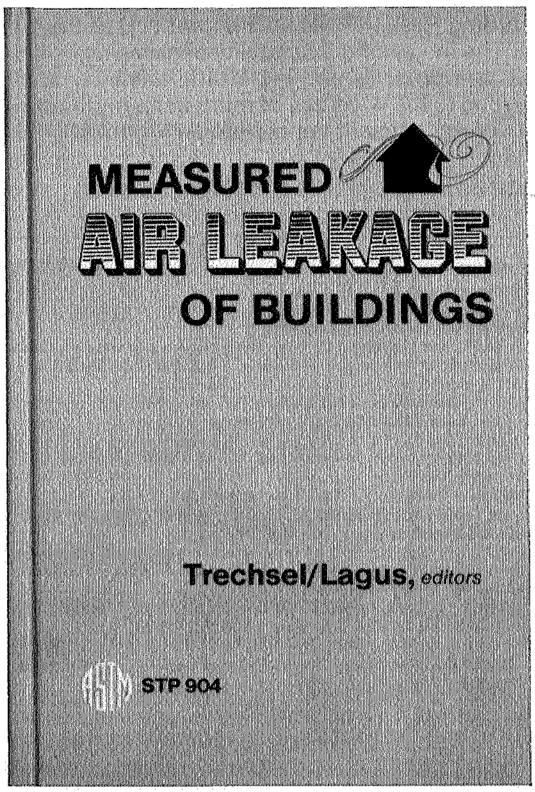


Published by: ASTM, 1916 Race Street, Philadelphia, PA 19103, USA. (ASTM Special Technical Publication 904, ASTM Publication Code Number (PCN) 04-904000-10, ISBN 0-8031-0469-3).

Measured Air Leakage of Buildings

**A symposium sponsored by ASTM Committee E–6 on Performance of Building Constructions, Philadelphia, PA, USA. 2 – 3 April 1984.
Editor: Heinz R. Trechsel and Peter L. Lagus.**

In contrast to the first symposium on air infiltration in 1978, when little measured data existed on air infiltration in residential buildings, this symposium reveals that today there are probably more than a thousand dwellings on which air infiltration data or pressurisation data, or both, exist. This session's papers summarise the state of all existing data on air infiltration, including data on measured infiltration rates in various building types and climates, and discussions on the related issues of mathematical modelling and prediction of air infiltration rates, methods for infiltration reduction and their effectiveness, and new proposed methods of measuring infiltration.

Papers are grouped into four sections:

- residential
- commercial and industrial
- techniques for measurements and infiltration reduction
- analysis

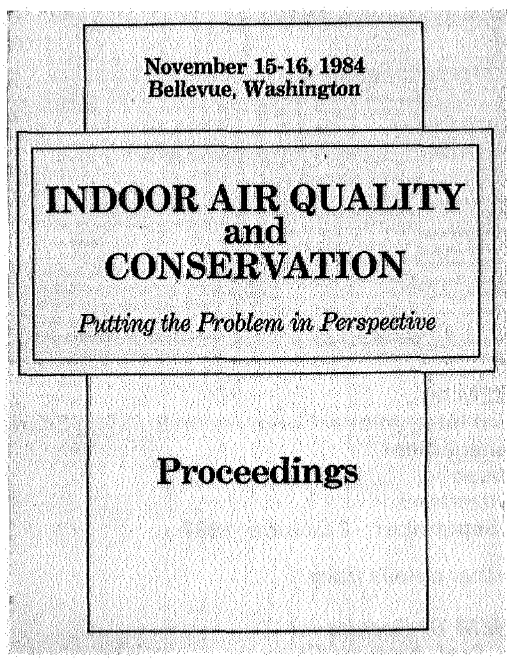
Indoor Air Quality and Conservation Putting the Problem in Perspective

Proceedings of Conference held in Bellevue, Washington, USA, 15–16 November 1984. Sponsored by Washington Energy Extension Service and Oregon State University Extension Energy Program.
Editor: Chuck Eberdt

These collected proceedings were produced initially from taped transcriptions of the presentations, which were updated by the presenters to ensure that the best available information was included. The contents include background information on the presenters and a record of the 'open forum' discussions.

Subjects covered include:

- The nature and magnitude of the problem
- Problems of radon
- Formaldehyde build-up in the home
- Residential indoor air quality
- The effect of moisture on other pollutants
- The epidemiology of indoor air problems
- Setting standards for recognising harmful concentrations in homes
- The effect of retrofit conversion measures
- The public's perspective
- Policy making in an uncertain environment
- The BPA environmental impact statement
- Policy, politics and indoor air pollution.



Published by: Energy Business Association, 300A Maritime Building, 911 Western Avenue, Seattle, Washington 98104, USA.

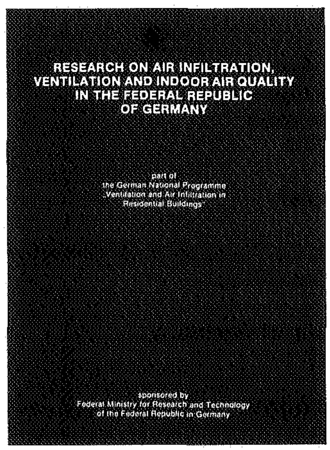
Research on Air Infiltration, Ventilation and Indoor Air Quality in the Federal Republic of Germany

A report prepared for IEA's Annex V, 'Air Infiltration and Ventilation Centre' by L. Trepte and A. Le Marié and sponsored by the Federal Ministry for Research and Technology of the Federal Republic of Germany.

In December 1985, the Federal Republic of Germany joined the International Energy Agency's Annex V, the 'Air Infiltration and Ventilation Centre (AIVC) as the 12th participant. This report describes and summarises German research and development activities in the areas of ventilation, air infiltration and indoor air quality.

The report includes sections on the structure and organisation of research and development in the Federal Republic of Germany, and an outline of standards, codes and regulations for ventilation and indoor air quality. It goes on to outline the German research and development programme, 'Ventilation and air infiltration in residential buildings,' with a general section on its background and aims, and a description of its projects.

Research and development in the field beyond the programme are considered, divided into sections under universities and institutes; Federal and state offices; non-profit centres, institutions and associations; and industry. Study groups and commissions are listed, and finally there is a section on the work of the Information Centre for Regional Planning and Building Construction (IRB) which is the central information agency in the Federal Republic of Germany for building construction, town planning, regional planning and housing.



Copies available, to participating countries only, from Dr. L. Trepte, Dornier Systems Gmbh, Postfach 1360, D-7990 Friedrichshafen 1, Fed. Rep. of Germany.
Available free-of-charge to participating countries

German Translation of AIVC Technical Note

AIC Technical Note 16
'Leakage distribution in buildings'
Technische Information AiC 16
'Verteilung der Undichtheiten in Gebäuden'

This technical note is now available in German. Translated by W.R. Schriever, Ottawa, Canada, it is available, to participating countries only, from Dr. P. Hartmann, EMPA, Section 176, Überlandstrasse, CH-8600 Dübendorf, Switzerland. Price: 10 SFr

Forthcoming Conferences

1. Workshop
'Atmospheric Electricity and Ions - Influence on Health and Comfort
WHO Office, Copenhagen, Denmark
11 and 12 December 1986 (re-scheduled from January 1987)

Further details from:

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2. 1987 ASHRAE Winter Meeting
New York Hilton, New York, USA
18 – 21 January 1987

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3. Infiltration Modelling for Single Family Residences
at: ASHRAE Annual Meeting 1987
Nashville
USA
Sponsored by: T.C.4.3, Ventilation Requirements and Infiltration

Further details from:

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Tel: (204) 474-2471

4. 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
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5. Refrigeration and Air Conditioning '87
(Exhibition)
10–12 February 1987

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6. ASTM Symposium
Design and Protocol for Monitoring Indoor Air Quality
Cincinnati, Ohio
USA
Week of 26 April 1987

Further details from:

ASTM
1916 Race Street
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7. Roomvent -87
Air Distribution in Ventilated Spaces
International Conference at the Royal Institute of Technology
Stockholm
Sweden
10–12 June 1987

Further details from:

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Box 5506
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8. Indoor Air '87
Berlin (West)
Germany
17–21 August 1987

Further details from:

Conference Secretariat
Indoor Air '87
c/o CPO Hanser Service GmbH
Schaumburgalee 12
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9. 8th AIVC Conference
Ventilation technology research and application
Germany
21–24 September 1987

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10. ICBEM '87
Third International Congress on Building Energy Management
Lausanne
Switzerland
28 September – 2 October 1987

Further details from:

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3rd fold (insert in Flap A)

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