Air Infiltration Review

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Air Leakage Characteristics and New Standards For Swiss Construction

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Introduction

In the last few years energy regulations have been introduced in many Swiss Cantons. The main goal of these regulations, relative to the building envelope, is to improve the insulation value. Consequently, typical current construction for new buildings is characterized by exterior wall and roof insulation U-values under 0.5 $W/m^2{\cdot}K$ and windows with triple glazing or its thermal equivalent.

These energy regulations, however, address the airtightness of buildings merely by setting a maximum allowable a-value for windows and doors, for example 0.2 $m^3/h{\cdot}m{\cdot}Pa^{2/3}$. This set value is based on the customary way of calculating the heating capacity requirement of buildings by considering air leakage from joints of apparent building components. Swiss guidelines establish three classes of window air leakiness for these calculations (Table 1).[1]

In reality the a-values of contemporary building components are substantially better than indicated in Table 1. In calculating the heating plant capacity, however, values under 0.2 $m^3/h{\cdot}m{\cdot}Pa^{2/3}$ are not used. This recognizes the presence of other undefined but existent joints and cracks. Accordingly, calculations always start off with an air change rate per hour of at least 0.3.

Construction of windows and doors	a_F ($m^3/h{\cdot}m{\cdot}Pa^{2/3}$)
Wooden framed windows without weatherstripping and wooden doors without weatherstripping	0.6
Wooden or combined wooden/metal framed windows with weatherstripping (Performance requirement group A of SIA 180/l)[2] and doors with weatherstripping	0.3
Metal, plastic or wooden framed windows with special weatherstripping (Performance requirement groups B and C of SIA 180/1) and doors with special weatherstripping (special orders)	0.2

Table 1. Calculation values for the airtightness of joints at windows and doors

Inside this issue:

In Switzerland, residential buildings are primarily naturally ventilated (via windows). For interior rooms (e.g. toilets, bathrooms or kitchens) exhaust ventilation controlled by a timer or the light switch is common. In older apartment buildings ventilation shafts without fans can often be found. Warm air heating systems are practically unheard of in Swiss construction. The sharply reduced heat losses of modern buildings, however, afford greatly improved pre-conditions for including air heating systems.

In office buildings the installation of ventilation and cooling systems is common, although the tendency is to specify air conditioning only where it really is essential. It is considered obvious that ventilation and cooling systems should be equipped with means for heat recovery.

Recently, it has become acknowledged that maximum airtightness of the building envelope should not always be the goal. Rather, a degree of airtightness should be sought which is appropriate for the situation. To provide a sound basis for such decisions, typical buildings have been systematically studied to determine their actual air leakage characteristics and accordingly the natural air change rates. Until now the studies have concentrated primarily on residential structures. Above all, these studies have striven to define levels of airtightness appropriate for the cases dependent on natural ventilation. In other countries the path being taken is to equip all new buildings with mechanical ventilation including heat recovery from exhaust air. This allows, and actually requires, as tight construction of the building envelope as possible. In Switzerland the percentage of residential buildings with mechanical ventilation will surely increase in the future, but a greater percentage will continue to be naturally ventilated.

Measurement methods

Measurement methods to determine values for the airtightness of the building envelope and the air exchange are:

- Pressurization measurement

- Air change measurement with a tracer gas.

In addition infrared photography can serve well in analyzing thermally weak areas of the building envelope.

The application of measurement methods has been reported in detail in documentation of the AIC, but a short review (focusing on new techniques) is provided here.

A new apparatus for pressurization tests is shown in Figure 1. It consists of an axial fan with continuously variable speed. Volumetric measurement of air-flow is achieved with calibrated intake nozzles. In the illustrated apparatus three sizes of nozzles are available. These permit measurements in the range from 400–8000 m^3/h. To facilitate transporting the device to the measurement site, the three nozzles can be placed concentrically one inside the other.

In order to assure that pressure difference and air change measurement results are comparable, at least within Switzerland, detailed measurement guidelines have been set out.[3,4] Recent years of experience have proved the guidelines to be valuable tools.

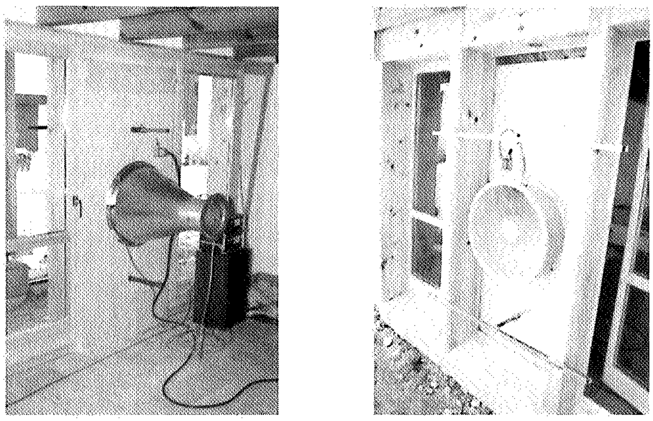

Figure 1. Apparatus for pressurization test

Results of two measurement projects

Table 2 gives results from pressurization tests for 34 apartments in five typical, massive, Swiss buildings constructed between 1963–1973 (a NEFF* project[5]). The n_{L50} values were found to be between 1.6 and 6.5 h^{-1} for apartments having windows without weatherstripping, and between 1.6 and 2.4 h^{-1} for apartments having windows with weatherstripping.

Within the framework of another measurement project,[6] 19 units of primarily new single-family houses of frame (light) or mixed construction were studied. The n_{L50} values of these units ranged from 2 to 18 h^{-1}, which is a very large variation. The houses with the largest air leakage rates were typically untight where different components come together, such as where roof meets wall.

Another common problem area is the living space directly under the roof. The airtightness of the roof construction in such instances is too often ignored. This results not only in adverse energy consequences but can also cause discomfort due to the unnecessarily high air change rate from the outside (draught problems). Further, it can lead to building physics problems, such as for example damage resulting from water vapour condensation.

Measured Apartment Unit	Without weatherstripping			With weatherstripping		
	Average	Range	Standard deviation	Average	Range	Standard deviation
A	4.1	2.7–6.5	1.21 (30%)	–	–	–
B	2.3	1.6–2.9	0.60 (26%)	–	–	–
C	2.5	2.2–3.4	0.50 (20%)	–	–	–
D	3.4	2.2–5.2	1.27 (38%)	1.8	(only 1 apt)	(only 1 apt)
E	2.2	2.2–2.3	0.08 (4%)	1.9	1.6–2.4	0.43 (23%)

Table 2. Results from the NEFF project*

*National Energy Research Foundation

The results of both the above mentioned Swiss research projects are shown in Figure 2 in an international comparison.[7]

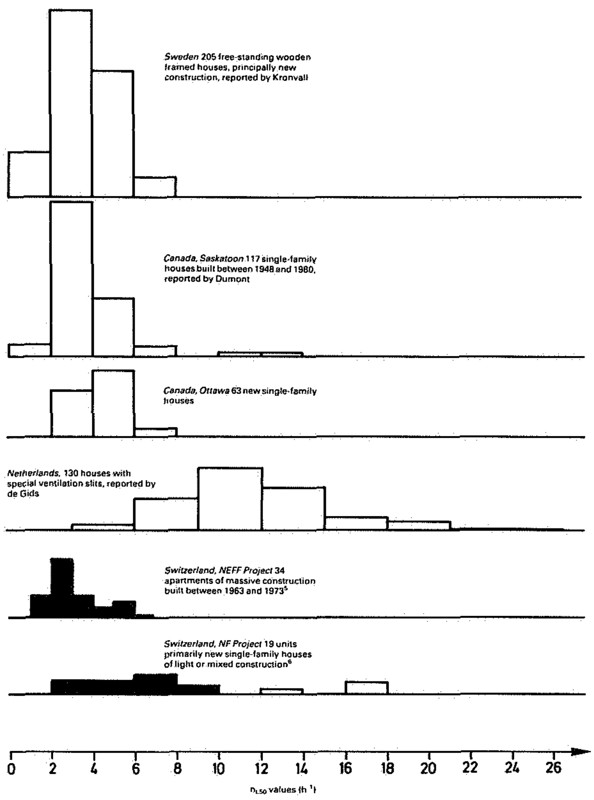

Figure 2. Results of the Swiss research projects compared internationally.

Recommendations for appropriate airtightness of buildings

Based upon the experience of these Swiss measurement campaigns, the author has made recommendations (shown in Figure 3) for appropriate levels of airtightness of the building envelope. These are valid for well insulated Swiss buildings. This year standard values in a similar form as presented here will be established by the Association of Swiss Engineers and Architects (SIA).[8] These standard values will be quickly put to use in the previously mentioned cantonal energy regulations.

Recommended airitghtness (n_{L50} values) can be read from the diagram in Figure 3 which shows three cases:

- without mechanical ventilation
- with mechanical exhaust air extraction without heat recovery
- with forced supply and exhaust air with heat recovery.

For **mechanical ventilation with forced supply and exhaust air,** the building envelope should be as tight as possible. This assures that most of the air exchange with outside air occurs via the ventilation system, where heat recovery can be efficiently put in operation. With current construction methods airtightness n_{L50} values under 2 h^{-1}can be achieved, as Figure 2 shows. Values greater than 3 h^{-1}in this case must be deemed unacceptable.

Ventilation systems should maintain the minimal outside air change rates and should be equipped with heat recovery.

Residential buildings **without mechanical ventilation** are still very common today. For these cases n_{L50} values between 2 and 4 h^{-1} are recommended. Residential structures with n_{L50} values above approximately 5 h^{-1} must certainly be classified as being too leaky. Conversely, cases

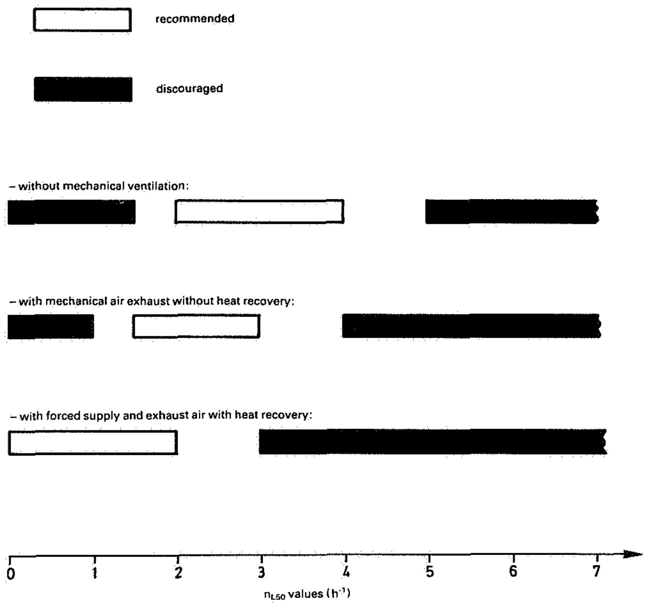

Figure 3. Provisional recommendations for the airtightness of the building envelope for residential construction

with n_{L50} values less than 1.5 h^{-1} have too little outside air exchange. Such instances cannot comply with the requirements for air hygiene or the avoidance of damage to the building construction.

Design solutions with **mechanical air exhaust** and make-up air via cracks and joints of the building construction should have n_{L50} values between 1.5 and 3 h^{-1}. These values are somewhat lower than those for design solutions without mechanical ventilation because the forced exhaust affords a certain level of fresh air intake.

Figure 3 reveals that, especially in the cases without mechanical ventilation or with forced exhaust air, values occur which are today neither recommended nor discouraged. It is to be hoped that these areas of uncertainty will occur less and less in the future.

It should also be noted that while complying with an appropriate global airtightness level for the building envelope, *local* occurrences of draughts from too large leakage sources can lead to discomfort. Such excessive leakage sources can be detected by smoke tubes, by pressurisation measurement or possibly by infrared photography.

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Empfehlung SIA 180/1
Winterlicher Wärmeschutz im Hochbau
(Measures on buildings with regard to winter time)

3. Impulsprogramm Haustechnik, U. Steinemann
Richtlinie zur Durchführung von Luftdurchlässigkeitsmessungen am Bau mittels stationärem Differenzdruck
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(Guidelines for pressurization measurements)

4. Impulsprogramm Haustechnik, C. Roulet
Richlinie zur Durchführung von Luftwechselmessungen mit Tracergas
erhältlich bei EMPA, Abt. Bauphysik, CH-8600 Dübendorf
(Guidelines for air change measurements with tracer gas)

5. NEFF-Projekt 226, U. Steinemann
Experimentelle Untersuchung der Undichtheiten an bestehenden Wohnbauten typischer Bauart
Phase 1: Messungen an fünf Mehrfamilienhäusern
(Results from the NEFF-project)

6. U. Steinemann, D. Michel
Luftdurchlässigkeit von Wohnbauten
3. Schweizerisches Status-Seminar Wärmeschutz-Forschung im Hochbau
(Results from two Swiss projects)

7. M. Bassett
Air Infiltration in New Zealand Houses
4th AIC Conference, 1983, paper 14

8. Schweizerischer Ingenieur- und Architekten-Verein
Empfehlung SIA 180
Wärmeschutz im Hochbau (not yet published)
(Measures on buildings with regard to winter and summer time)

9. Planungshilfsmittel zur Kontrolle des Luftaustausches in Gebäuden
Seminar vom 3. April 1984 in Bern
erhältlich bei EMPA, Abt. Bauphysik, CH-8600 Dübendorf
(Planning aids in the field of air infiltration)

AIR MOVEMENT – A Numerical Prediction Technique

G.E. Whittle
Building Services Research and Information Association, Bracknell, U.K.

Introduction

Air movement within enclosures, which may result from a combination of infiltration, mechanical ventilation and convective heat transfer effects, is important for considerations of thermal comfort, ventilation efficiency and energy conservation.

Until quite recently the prediction of air movement relied extensively on empirically obtained data which defined, for example, the performance of air jets, and convective heat transfer from surfaces. Techniques are now being introduced from the field of computational fluid dynamics which allow a 'whole-field' prediction of air movement based on the solution of the conservation equations.

It is intended here to briefly review a predictive technique which is based on the numerical solution of the partial differential equations using a finite volume formulation and which can be readily applied to this problem area. The use of the method is illustrated by example.

The Conservation Equations

The equations which govern air flow and convective heat transfer are the conservation equations of momentum, energy and mass. These, together with hydrodynamic and thermal boundary conditions and a turbulence model, form the basis of any rigorous approach to predicting air movement within enclosures.

The momentum equations, which are often referred to as the Navier-Stokes equations[1], comprise up to three component equations, one for each co-ordinate direction. For example, in a two-dimensional flow field, that is one which can be fully described on a plane through the flow domain where the component of fluid velocity and gradients of fluid properties normal to the solution plane are zero, only two components of the momentum equations would be applied.

Having manipulated the equations to represent turbulent flow in terms of mean-flow velocity components, temperature and density, etc., the conservation equations are shown below for the special case of two-dimensional flow in a cartesian co-ordinate system (x,y).[2, 3]

Momentum – U component

$$\underbrace{\frac{\partial(\rho U)}{\partial t}}_{\text{transient term}} + \underbrace{\frac{\partial}{\partial x}(\rho UU) + \frac{\partial}{\partial y}(\rho VU)}_{\text{convection}} =$$

$$\underbrace{-\frac{\partial p}{\partial x}}_{\text{pressure gradient}} + \underbrace{\frac{\partial}{\partial x}(\mu_{eff}\frac{\partial U}{\partial x}) + \frac{\partial}{\partial y}(\mu_{eff}\frac{\partial U}{\partial y})}_{\text{diffusion}} + \underbrace{S_U}_{\text{additional 'source' term}} \qquad (1)$$

– V component

$$\frac{\partial(\rho V)}{\partial t} + \frac{\partial}{\partial x}(\rho UV) + \frac{\partial}{\partial y}(\rho VV) =$$

$$-\frac{\partial p}{\partial y} + \frac{\partial}{\partial x}(\mu_{eff}\frac{\partial V}{\partial x}) + \frac{\partial}{\partial y}(\mu_{eff}\frac{\partial V}{\partial y}) - \underbrace{(\rho - \rho\infty)\,g}_{\text{buoyancy term}} + S_V \qquad (2)$$

Energy

$$\frac{\partial(\rho T)}{\partial t} + \frac{\partial}{\partial x}(\rho UT) + \frac{\partial}{\partial y}(\rho VT) =$$

$$\frac{\partial}{\partial x}(\Gamma_{eff}\frac{\partial T}{\partial x}) + \frac{\partial}{\partial y}(\Gamma_{eff}\frac{\partial T}{\partial y}) + S_T \qquad (3)$$

Mass

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho U) + \frac{\partial}{\partial y}(\rho V) = 0 \qquad (4)$$

where
U, V = velocity components of mean flow
t = time
ρ = density
p = pressure
g = gravity
T = temperature
μ_{eff} = diffusion coefficient for momentum
Γ_{eff} = diffusion coefficient for temperature

S_U and S_V are additional viscous terms whose influence is small except where changes in fluid properties are considerable. Similarly the term S_T, which represents heat generation by viscous dissipation, is small and can be neglected in the processes being considered.

For isothermal flows where viscous dissipation is zero, where the boundaries of the flow domain are adiabatic and where there are no heat sources (or sinks) within the flow field, then the energy equation would become redundant.

In the above equations the laminar viscosity from the Navier-Stokes equations is replaced by an effective viscosity (diffusion coefficient) which will generally be orders of magnitude larger to account for the enhanced diffusional effects in turbulent flow.

In many situations the steady-state version of the equations are appropriate to define a flow field; in this case the transient terms would be zero. Transient effects are generally only of significance when studying changes which take place on a time scale of the order of seconds or minutes. An example of where this is important is in the study of smoke movement in an enclosure. Smoke or contaminant concentrations can be predicted using a convection-diffusion equation of similar form to Equation 3.

The diffusion coefficients are predicted in references 2 and 3 from a two-equation ($k - \epsilon$) model of turbulence, where k is the kinetic energy of turbulence and ϵ its dissipation rate (see also reference 4).

Both k and ϵ are predicted within the flow field using an equation similiar to Equation 3.

The $k - \epsilon$ model is the most widely used model of turbulence. Its value is in predicting effective diffusion coefficients and in quantifying the energy in the turbulent fluctuations within the flow field. It does, however, still rely on the use of empirically obtained constants.

The Solution of the Equations

A feature of Equations 1 – 3 is the similarity of form. This is used to advantage in the method of expressing the equations in 'discretised' or 'difference' form and in the numerical solution sequence.

The conservation equations express velocity components and fluid properties as continuous functions throughout the flow field. A procedure for solving the equations is to integrate them over finite control volumes and represent them in numerical, discretised form with the variables expressed at specific locations on a mesh of grid nodes within the flow domain. Each of the conservation equations are thus replaced by a set of linear algebraic equations (one equation for each grid node) which describe variables at grid nodes in terms of the variables at surrounding nodes. In obtaining a solution each set of equations is solved in turn. Because of non-linearities in the partial differential equations an iterative solution scheme must be adopted.

In representing the momentum and energy equations in numerical form, a 'hybrid' formulation is used to express the convective and diffusive fluxes across the boundaries of each control volume.[3] A typical control volume is shown in Figure 1.

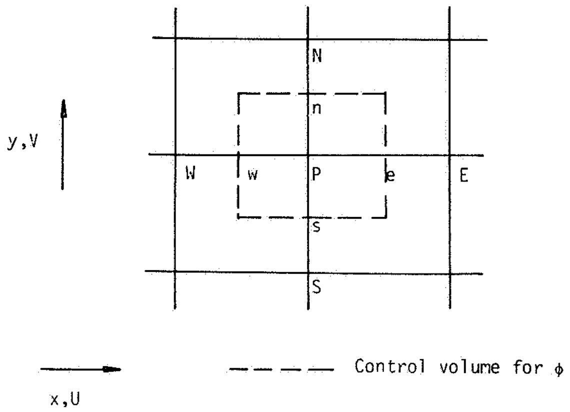

Figure 1. A control volume

It is claimed[2, 3] that the 'hybrid' formulation provides both accuracy and numerical stability of the solution scheme. In practice it is convenient to define a staggered grid system, as shown in Figure 2. Here the grids for U and V are displaced from the grid for the remaining solution variables. The reasons for adopting this approach are for simplicity in applying the pressure gradient terms in the momentum equations, and in specifying the special form of the mass continuity equation.

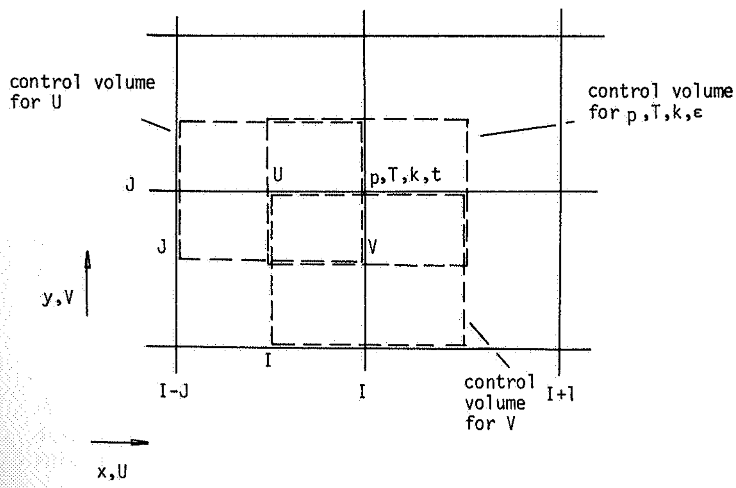

Figure 2. Staggered grid system

In solving each set of equations (one set for each variable, U, V, T etc.,) it is convenient and economical in computing requirements to use the Tri-Diagonal Matrix Algorithm (TDMA). The application of the TDMA, which here is the procedure of integrating along a grid line, is repeated in a line-by-line manner until the whole flow domain is swept. Stability of the sequence is encouraged by damping the changes in variable from one iteration to the next (under-relaxation).

The conservation equations (Equations 1 – 4) do not provide a ready means of calculating the pressure field. The way forward is to derive relationships for the rates of change of velocity components with pressure difference from the momentum equations and to combine these into a special form of the mass continuity equation. The resulting equation being solved for pressure correction at each grid node using the TDMA. The pressure and velocity fields are then updated.

The solution procedure outlined above is known as the SIMPLE (Semi-Implicit Method for Pressure Linked Equations) algorithm.[3] A number of enhancements to this algorithm have also been developed.[5]

Boundary Conditions

In order to obtain a solution to the equations, boundary values of all variables must be applied either directly or through a boundary flux. If infiltration or mechanical ventilation effects are present then the velocity components and air temperature at the inlet to, and outlet from, the flow domain must be prescribed.

In the case of turbulence modelling, a wall function approach is appropriate. These are special formulae for dealing economically with the steep variations in flow properties near surfaces.

When solving the energy equation it is necessary to prescribe surface temperatures or surface fluxes, as appropriate. Radiant energy transfer from surfaces can be modelled either by an external calculation or through an extension to the above model.

An Application of the Method

As an example of the general approach described above, a prediction has been undertaken of the air movement and temperature distribution in a perimeter module of a building. The enclosure considered is a rectangular shaped air conditioned office space in which the influence of winter heat losses is examined. The office space is sized 5m x 2.8m height and has one external fully glazed wall. Supply air at a temperature of 27°C enters the enclosure through a diffuser located in the ceiling adjacent to the glazing. The supply air flow rate is 50 litre/s per metre run of diffuser and the discharge velocity is 2.5m/s. The flow has been computed on a two-dimensional plane through the flow field.

Figures 3 and 4 show a velocity vector plot and temperature contours. The air movement pattern is characterised by a down-wash of air from the cold glazing. The supply jet under the influence of buoyancy forces was not able to counteract the down-wash. In this case the vertical temperature gradient combined with the cool air from the glazing results in an unacceptable thermal environment. The solution was obtained on a Prime minicomputer, requiring approximately ten minutes of cpu time. Other applications exist in the field of ventilation efficiency for contaminant control, and in the study of smoke movement within buildings.[6]

A further application of numerical models relates to external air flows around buildings. Here, there exists the potential to use a model such as is described above as a numerical wind tunnel to predict pressure distributions over building surfaces.[7]

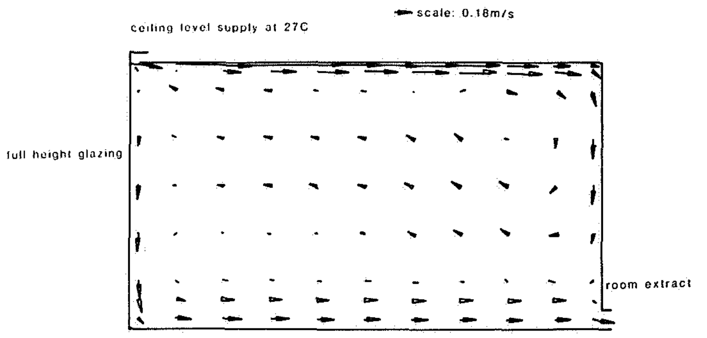

Figure 3. Velocity vector plot: winter heating

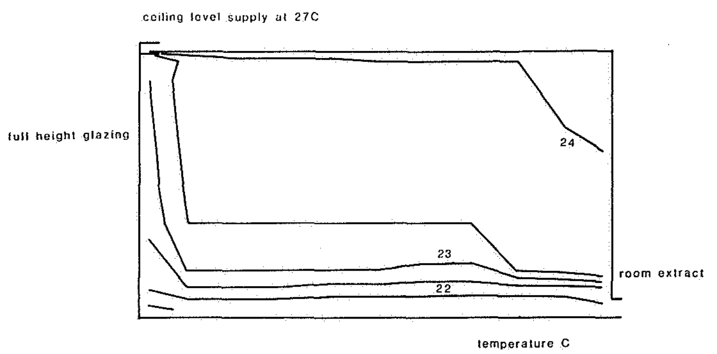

Figure 4. Temperature contours: winter heating

Concluding Remarks

The numerical procedures which have been briefly reviewed above form the basis of many fluid dynamics computer programs. They offer the ability to compute full three-dimensional steady-state and transient flow regimes and they provide a powerful and comprehensive predictive tool in air movement studies. However, the numerical techniques are still at a fairly early stage in development and so it is vital that proper engineering judgement be exercised in applying and interpreting the output from such codes.

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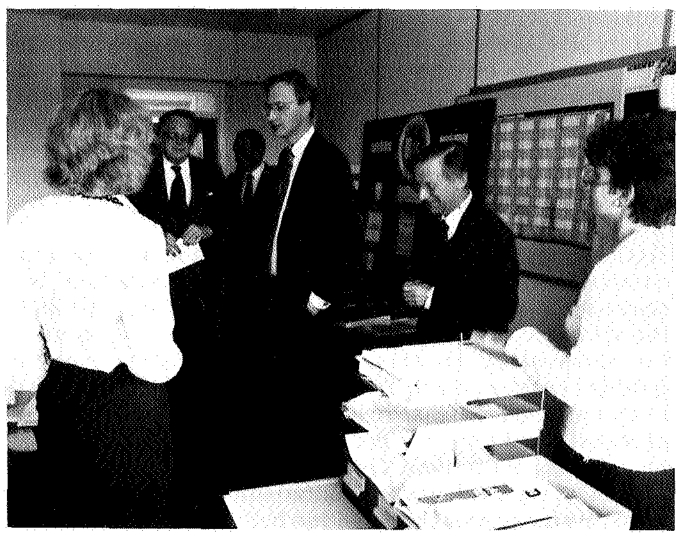


Visit to AIC by Government Minister

The AIC recently welcomed Sir George Young, Bt., MP, UK Parliamentary Under Secretary for the Department of the Environment, accompanied by Mr Ian Macpherson and Mr John Tory of the Department of the Environment.

They were given a brief review of the structure of the AIC and shown the functioning of the information service and some of the technical work undertaken by the AIC staff.

Book Reviews

Moisture Problems in Residential Construction: Separating Myth from Reality

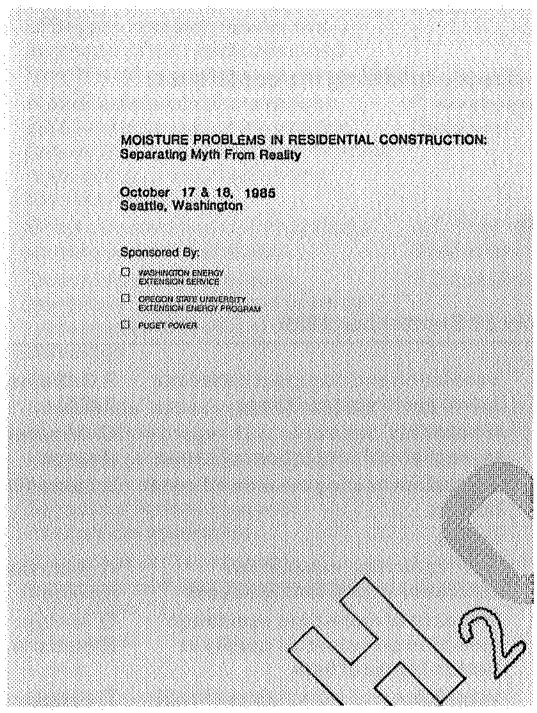
October 17 and 18, 1985
Seattle, Washington

This is a collection of papers by several well-known research experts from a seminar on moisture in housing, aimed at making house builders and others more aware of potential moisture problems and how to avoid them.

The papers vary from general checklists of sources of moisture and potential problems to more in-depth studies of specific potential problem areas such as wood-frame walls and attic condensation. Results of field studies in various regions within the USA are presented to give an idea of the types of problems that are most likely to be encountered under the different climatic conditions. The effects of retrofitting houses by addition of wall insulation without a vapour barrier are described in detail for two locations: Portland, Oregon with a mild climate and Spokane, Washington with a colder climate. In both cases no substantial moisture damage was found.

Similarly studies of wood-frame walls in a test situation show that there is no high potential for decay in any of the materials of the walls tested.

Condensation damage can best be avoided by paying attention to detail during house construction to ensure that there will be as few leaks as possible that will permit room air to enter concealed spaces. However as moisture problems already exist in a proportion of the housing stock, the basic control strategies for dealing with the situation are explained.



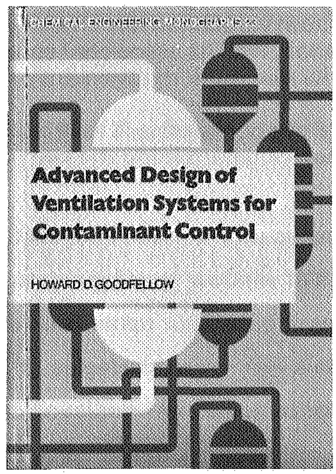
A short bibliography is included but unfortunately no summaries of the panel discussions which must surely have raised some interesting points.

Available from: Washington Energy Extension Service, Seattle University, Seattle, WA 98122, USA. Price $7.

Advanced Design of Ventilation Systems for Contaminant Control

Howard D. Goodfellow

This is essentially a technical reference book covering all aspects of designing ventilation systems for contaminant control. Ventilation should be an integral part of the design process and a rigorous application of the systems approach is followed in this book. It focuses on control of contaminants to acceptable levels as the prime objective, although attention is also given to control of heat and humidity, and prevention of risks and explosions.



It progresses in a logical way from the fundamental physics of fluid flow and fluid-particle systems through the design parameters and technical specifications of industrial ventilation to design of specific systems. Dust control, fume control and other specialised ventilation techniques, such as dilution ventilation, recirculation of filtered air, design of enclosures for buoyant and non-buoyant sources, laboratory fume hoods, welding fume control and air curtains and air jets, are examined. Threshold Limit Values are discussed as a preliminary step to understanding the degree of risk. However it is emphasised that these are only guidelines and that individual countries' regulations and requirements may differ.

Numerous examples are given of practical applications to solving industrial ventilation problems. A unique feature is the development of recommended subject classifications for the ventilation field. Each chapter is concluded with an extensive list of references.

The specific design data presented in the Appendices facilitate the use of the book as a complete reference source. Appendix A contains a list of Threshold Limit Values for over 600 chemical substances. Appendix B contains ventilation system design charts. Appendix C presents typical technical specifications with questionnaires for the major equipment of ventilation systems. Appendix D covers the necessary ventilation design charts for dust control. Appendix E presents a standard calculation procedure for the design of an electric arc furnace fume system.

ISBN 0-444-42546-2.

Available from: Elsevier Science Publishers, P.O. Box 211, 1000 AE Amsterdam, The Netherlands. Price Dfl. 395.00.

Or in the USA/Canada: Elsevier Science Publishers Co. Inc. P.O. Box 1663, Grand Central Station, New York, N.Y. 10163. Price US$ 146.25.

7th AIC Conference

'Occupant Interaction with Ventilation Systems'

29 September – 2 October 1986
Moat House International Hotel, Stratford-upon-Avon, UK

AIC's 7th Annual Conference to be held in collaboration with IEA Annex VIII – "Inhabitants' behaviour with regard to ventilation"

Energy use in buildings is greatly influenced by occupant behaviour, especially in relation to ventilation. Often the action by occupants results in ventilation rates much greater than really required with the consequent waste of energy. On the other hand, too little ventilation, with its associated condensation and indoor air quality problems, can result from the maintenance of ventilation below the minimum requirement or by failure to respond to the intermittent need for increased ventilation.

The objective of this conference is to bring together those with knowledge or interest in this vital aspect of ventilation control with the intention of determining the key parameters governing occupant influence on building energy performance. Topics include:

- reasons for occupants' attitude and reactions to ventilation
- measurement of window opening habits or other ventilation control behaviour
- consequences of behaviour patterns on energy consumption and indoor air quality (case studies and calculations)
- user-acceptable ventilation strategies
- benefits of advice to user on ventilation control.

The conference programme draws upon the expertise of authors from 13 countries making this one of the Air Infiltration Centre's most international of conferences.

Registration forms and complete programme details are available from your Steering Group representative (see back cover of newsletter) or direct from the AIC Centre (contact Jenny Elmer on tel. 0344 53123, telex 848288).

Registration fee, including up to 3 nights inclusive accommodation is £260 sterling (£235 sharing). Final date for receipt of registration forms is 22 August 1986.

For those unable to attend, full conference proceedings will be available directly following the conference.

Programme

Monday 29 September 1986

11.00	Departure of coach from London Heathrow Airport	
13.00	Arrival at conference venue/ registration/lunch	
14.30	Keynote address	R. Courtney (UK)
	Requirements for adequate user-acceptable ventilation installations in dwellings	V. Meyringer et al (W. Germany)
	Ventilation, air infiltration and building occupant behaviour	D.J. Harrje et al (USA)
16.00	Afternoon tea	
16.30	A study of window opening in 18 low energy houses	J.P. Lilly et al (UK)
	Occupants' influence on air change in dwellings	B. Kvisgaard et al (Denmark)
	The influence of occupant behaviour on indoor air quality – a case study	Z. Szalay et al (Hungary)
19.00	Reception	
19.45	Conference dinner	

Tuesday 30 September 1986

08.30	Ventilation and occupant behaviour in two apartment buildings	R.C. Diamond et al (USA)
	Inhabitants' behaviour with regard to mechanical ventilation in France	Cl. Moye et al (France)
	Ventilation heating systems of small houses	J. Laine (Finland)
10.15	Coffee	
10.45	User-controlled exhaust fan ventilation in one-family houses	A. Blomsterberg (Sweden)
	Influence of night-time ventilation reduction on indoor air quality in Danish blocks of flats	O. Nielsen (Denmark)
	Ventilation and indoor air quality in new Norwegian detached dwellings	T. Haugen et al (Norway)
12.30	Discussion	
13.00	Lunch	
14.00–17.00	Free afternoon	
18.00–19.30	Dinner	

19.30–	Poster Sessions and demonstration of AIRBASE:	
	Poster 1: Ventilation strategies and occupants' behaviour	J. Railio (Finland)
	Poster 2: Spatiotemporal control of mechanical exhaust air ventilation	R. Holmberg (Finland)
	Poster 3: Design of occupancy related ventilation control system for a new entertainment centre in Hong Kong	W.L. Lee et al (UK)
	Poster 4: User survey of range-exhaust fans	N. Nagda et al (USA)
	Poster 5: Home owner response to air sealing education	D. Valentine et al (USA)
	Poster 6: The effects of control strategies on natural ventilation cooling of residential buildings	S. Byrne et al (USA)
	Poster 7: The use of passive ventilation systems for condensation control	R.E. Edwards et al (UK)
	Poster 8: Air quality in the indoor environment	E. Sterling et al (Canada)
	Poster 9: New look at occupant behaviour in ventilation – a sociological perspective	F. Hainard et al (Switzerland)
	Poster 10: Comparison of research results concerning the influence of climatic data on window use	J. Mont et al (Belgium)
	Poster 11: Comparison of research results concerning the effect of window use on ventilation rates	J. Mont et al (Beglium)
	Poster 12: Use of ventilation provisions in practice	J.E.F. van Dongen (Netherlands)
	Poster 13: Effects on ventilation behaviour of inhabitants in residential buildings	L. Trepte (Germany)
	Poster 14: Seasonal effects on window behaviour	W.F. de Gids et al (Netherlands)
22.00	Close of session	

Wednesday 1 October 1986

Session on IEA Annex VIII 'Inhabitants' behaviour with regard to ventilation'

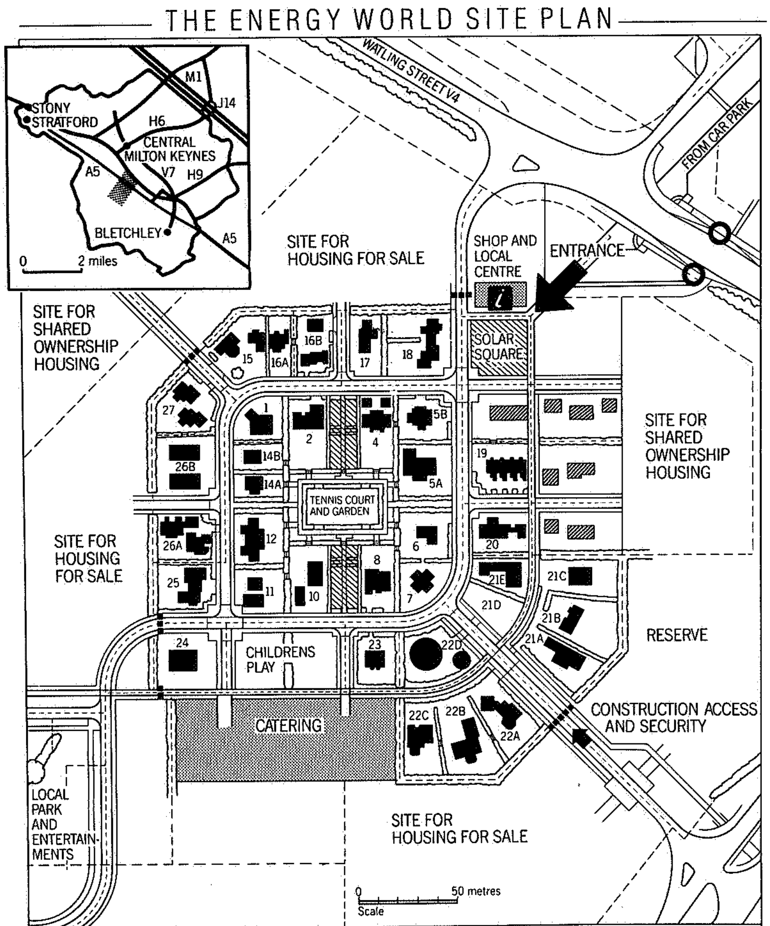
08.30	Inhabitants' behaviour with regard to ventilation. Preliminary synthesis of Belgian research results and synthesis of the results obtained from the other countries of Annex VIII	C. Dubrul (Belgium)
	A detailed statistical analysis on 2800 social houses of the relation between living patterns (e.g. window use), energy consumption and humidity problems	P. Wouters et al (Belgium)
	Effect of instructions to inhabitants on their window behaviour	J.C. Phaff et al (Netherlands)
	Determinants of ventilation behaviour. A statistical analysis on two samples of (i) 40 and (ii) 3000 dwellings	F. Doue (Belgium)
10.15	Coffee	
10.45	Inhabitants' behaviour with respect to ventilation	J.E.F. van Dongen (Netherlands)
	Influence of the meteorological conditions on the inhabitants' behaviour in dwellings with mechanical ventilation	E. Erhorn (Germany)
	A new look at the occupant behaviour with respect to natural ventilation	F. Hainard et al (Switzerland)
12.30	Discussion	
13.00	Lunch	
14.00	Ventilation requirements for moisture control in different climates	J. Kronvall (Sweden)
	The use of passive ventilation systems for condensation control in dwellings and their effect upon energy consumption	R.E. Edwards et al (UK)
	Measurement of carbon dioxide in indoor air to control the fresh air supply	I. Fecker et al (Switzerland)
15.45	Afternoon tea	
16.15	Design and operation of mechanical ventilation systems in office buildings	A.K. Persily (USA)
	Density driven flows through open doors	D.E. Kiel et al (Canada)
17.00	Discussion and summing-up	
19.30	Dinner	

Thursday 2 October 1986

08.30	Coach departs from hotel for technical visit
09.30	Technical visit to Energy Park, Milton Keynes
13.00	Close of conference and lunch at Milton Keynes
14.00	Coach returns from Milton Keynes to London Heathrow Airport
16.00	Coach arrives at London Heathrow Airport

Venue for Technical Visit

'Energy World', Milton Keynes



PLOT	DEVELOPER						
1 & 14B	C P Roberts Construction	10	Hosby House (Danish)	19	K Phillips	22C	Barratt
2	ECD/Hughes Homes	11	Stepnell/SIAB (Swedish)	20	Abbey National	22D	K C Developments
4	Pilkington	12	Hedlund (Swedish)	21A	Lifestyle 2000 (Canadian)	23	Constructive Individuals
5A	Thorncroft	14A	D F W Golding	21B	Wimpey	24	Haslam Homes
5B	Mowlem	14B	With plot 1	21C	ASPP	25	EME/Prowting
6	Scan Select (Danish)	15	Laing	21D	Vacant	26A	Erostin
7	Multitherm Easibuild	16A	Llewellyn	21E	Scan Select (Danish)	26B	Denson/W Watson Builders
8	Broseley/CDA	16B	Persimmon	22A	Salvesen	27	S & S
		17 & 18	British Gas	22B	NCB		

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Forthcoming Conferences

1. International Climatic Architecture Congress
Louvain-la-Neuve, Belgium
1–3 July 1986

Further information from:

A. de Herde
Universite Catholique de Louvain
Unite Architecture
1 Place du Levant
B-1348 Ottignies-Louvain-la-Neuve
Belgium

Tel: (010) 43.22.23 – 43.21.39
Tlx: 59037 UCL B

2. CIBSE 5th International Symposium
The Use of Computers for Environmental Engineering Related to Buildings
Bath, United Kingdom
6–9 July 1986

Further information from:

Member Services Department
Chartered Institution of Building Services
222 Balham High Road
London
SW12 9BS
Great Britain

3. CIBSE/ASHRAE 1986 Conference
Dublin, Republic of Ireland
14–17 September 1986

Topics:

- *Building design construction and management*
- *Equipment advances*
- *Case studies*

4. Advanced Building Technology
10th CIB Congress
Washington DC, USA
21–26 September 1986

Noël J. Raufaste
Director CIB.86
Center for Building Technology
National Bureau of Standards
Gaithersburg
MD 20899
USA

5. 7th AIC Conference
Occupant interaction with ventilation systems
Stratford-upon-Avon, England
29 September – 2 October 1986

Further details from:

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Air Infiltration Centre
Old Bracknell Lane West
Bracknell
Berkshire
RG12 4AH
Great Britain
Tel: +44 344 53123
Telex: 828488 BSRIAC G

6. 2nd International Conference
'System simulation in buildings'
Chateau de Colonster, University of Liege, Belgium
1–3 December 1986

Further information from:

J. Lebrun
Thermodynamics and Building Physics Laboratories
University of Liege
Avenue des Tilleuls 15 – Bat. D1
B–4000 Liege
Belgium
Tel: (041) 52 01 80 Ext. 367/416

7. Symposium
'Guidelines for air infiltration, ventilation and moisture transfer'
Worthington Hotel, Fort Worth, Texas, USA
2–4 December 1986

Further information from:

Building Thermal Envelope Co-ordinating Council
1015 15th Street NW
Suite 700
Washington DC 20005
USA

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

Further information from:

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

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

Call for papers:

Building energy management is a fast growing and rapidly changing field of considerable scientific, technical as well as economic and social importance. The aim of ICBEM '87 is to present the state-of-the-art together with ongoing research in selected fields such as

- *ventilation, air movement in buildings, air quality*
- *control and regulation of heating and ventilation*
- *field measurement and auditing*
- *building planning process and design tools*
- *energy strategies and the occupants*
- *solar energy use*
- *daylighting and artificial lighting*
- *building concepts for hot climates*
- *building regulatory process*
- *case studies on the above listed topics*

Preliminary abstracts should be about 200 words in length and typed in English. The abstracts must be received by the Program Committee not later than 1 June 1986.

ICBEM '87 Secretariat
p.a. Prof. Andre P. Faist
EPFL – LESO Building
CH 1015 Lausanne
Switzerland
Tel: 021 47 11 11
Telex: 24478

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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 AIC publications. *Unrestricted availability, free-of-charge.*

Recent Additions to *AIRBASE*
Quarterly bulletin of abstracts added to *AIRBASE*, AIC'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 AIC library. *Bulletin and copies of papers available free-of-charge to participating countries* only.*

TECHNICAL NOTES

AIC-TN-1-80 – Superseded by AIC-TN-16-85.

AIC-TN-2-80 – Superseded by AIC-TN-7-81.

AIC-TN-3-81 – Superseded by AIC-TN-8-82.

AIC-TN-4-81 – Superseded by AIC-TN-10-83.

AIC-TN-5-81 – Allen, C.
'AIRGLOSS: Air Infiltration Glossary (English edition)', 124pps.
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', 58pps.
A supplement containing translations of the terms published in AIRGLOSS. *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', 56pps.
A supplement containing translations of the terms published in AIRGLOSS. *Available free-of-charge to participating countries.* Price £7.50 to non-participating countries.*

AIC-TN-5.3-84
'AIRGLOSS: Air Infiltration Glossary (Italian Edition)' 80pps.
An Italian version of the original English glossary (TN-5-81). *Available free-of-charge to participating countries.* Price £10 to non-participating countries.*

AIC-TN-6-81 – Allen, C.
'Reporting format for the measurement of air infiltration in buildings', 56pps.
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-participants.*

AIC-TN-7-81 – Superseded by AIC-TN-12-83.

AIC-TN-8-82 – Superseded by AIC-TN-15-84.

AIC-TN-9-82 – Superseded by AIC-TN-11-83.

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', 60pps.
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* only.*

AIC-TN-11-83 – Liddament, M., Allen, C.
'The validation and comparison of mathematical models of air infiltration', 124pps.
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* only.*

AIC-TN-12-83 – Liddament, M.
'1983 Survey of current research into air infiltration and related air quality problems in buildings', 100pps.
3rd worldwide survey by AIC, containing over 170 replies from 22 countries. Produced in two sections: an analysis in tabular form of survey results, followed by reproduction in full of research summaries, and appendix containing names and addresses of principal researchers. *Available free-of-charge to participating countries* only.*

AIC-TN-13-84 – Allen, C.
'Wind Pressure Data Requirements for Air Infiltration Calculations', 124pps.
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* only.*

AIC-TN-13.1-84
'1984 Wind Pressure Workshop Proceedings', 164pps.
Report of written contributions and discussion at Workshop held in March 1984, Brussels. *Available free-of-charge to participating countries* only.*

AIC-TN-14-84 – Thompson, C.
'A Review of Building Airtightness and Ventilation Standards', 74pps.
Lists and summarises airtightness and related standards to achieve energy efficient ventilation. *Available free-of-charge to participating countries* only.*

AIC-TN-15-84 – Superseded by AIC-TN-18-86.

AIC-TN-16-85 – Allen, C.
'Leakage Distribution in Buildings', 46pps.
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AIC-TN-17-85 – Parfitt, Y.
'Ventilation Strategy – A Selected Bibliography', 28pps.
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, 104 pps.
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.*

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).

CONFERENCE PROCEEDINGS

- No. 1 'Instrumentation and measuring techniques'.
  1st AIC Conference, 6–8 October 1980, Windsor, Berkshire, UK, 372pps, £35.00 sterling.
- No. 2 'Building design for minimum air infiltration'.
  2nd AIC Conference, 21–23 September 1981, Stockholm, Sweden, 216pps, £15.00 sterling.
- No. 3 'Energy efficient domestic ventilation systems for achieving acceptable indoor air quality'.
  3rd AIC Conference, 20–23 September 1982, London, UK, 432pps and Supplement 160pps. Total cost £23.50 sterling.
- No. 4 'Air infiltration reduction in existing buildings'.
  4th AIC Conference, 26–28 September 1983, Elm, Switzerland, 342pps and Supplement 52pps. Total cost £16.00 sterling.
- No. 5 'The implementation and effectiveness of air infiltration standards in buildings'.
  6th AIC Conference, 1–4 October 1984, Reno, Nevada, USA, 376pps and Supplement. Total cost £16.00 sterling.
- No. 6 'Ventilation strategies and measurement techniques'.
  6th AIC Conference, 16–19 September 1985, Het Meerdal Centre, Netherlands, 536pps and Supplement. Total cost £22 sterling.

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