Air Infiltration Review

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Research Report from Norway

Wind pressure measurements on a rotatable test house

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Introduction

At The Norwegian Building Research Institute, Division Trondheim, we have been working on a research project involving wind pressure measurements. The main goal of the project is to get more information about the influence of wind pressure on the heat loss from timber frame walls with ventilated airspace between the wind barrier and the cladding. The project is divided into three parts: calculations, hot-box measurements and wind pressure measurements. The project is funded by The Royal Norwegian Council for Scientific and Industrial Research as well as 13 producers of wind barriers or thermal insulation.

Wind pressure measurements

The wind pressure measurements, which started in November 1985, are necessary to get input values for the calculations and the hot-box measurements. Other goals were to obtain more correct wind pressure coefficients for use in air infiltration models, and to study the possibility of reducing the pressure variations outside the wind barriers by connecting the airspaces behind the claddings and below the roof to a single pressure equalization chamber. This is of interest for the reduction of wind induced infiltration in common constructions, but is also of special importance for developing simple constructions based on the dynamic insulation principle.

A test house has been equipped with instrumentation for wind pressure measurements. By use of an electromotor, the test house can be rotated to any desired position relative to the wind direction. The basic dimensions of the house are: length 9 m, width 5 m, height to the top of the roof 6 m, and roof angle 36°. The location of this house is on an open test area at the top of Tyholt Hill in Trondheim.

By use of 20 pressure transducers (Furness) and a fast data logging system (3530 ORION) the wind pressure at 20 points is recorded simultaneously. By exchanging the plastic tubes connected to the pressure transducers, the wind pressure at 52 different points is measured.

Two groups of pressure points are located on a short wall and four groups on a long wall. The eight pressure points in each group are distributed along a vertical line as shown in

Inside this issue:

Figure 1 (four on the outside, two in the air space behind the cladding, one on the wall above the cladding and one in the attic 20 mm from the edge). In addition, the indoor pressure and the pressure in the middle of the attic are measured. The static pressure measured 10 m above the ground by a mast on the roof, serves as reference for the pressure transducers. The dynamic pressure measured at the same place is used when calculating wind pressure coefficients.

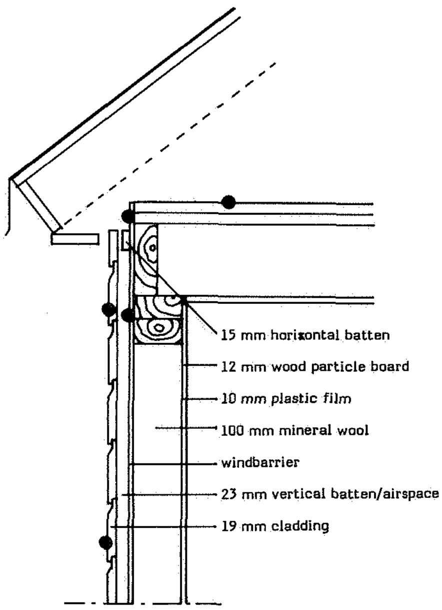

Figure 1: Example of construction showing the location of measuring points for wind pressure.

As the wind pressure behind the cladding will be influenced by construction details like the gaps at top and bottom of the airspace behind the cladding, it is necessary to make wind pressure measurements for various construction solutions as well as at various wind approach angles. So far we have investigated three variants. We plan to continue the wind pressure studies on other types of constructions and construction details in 1986. An example of measured pressure distribution at the middle of a long wall is shown in Figure 2.

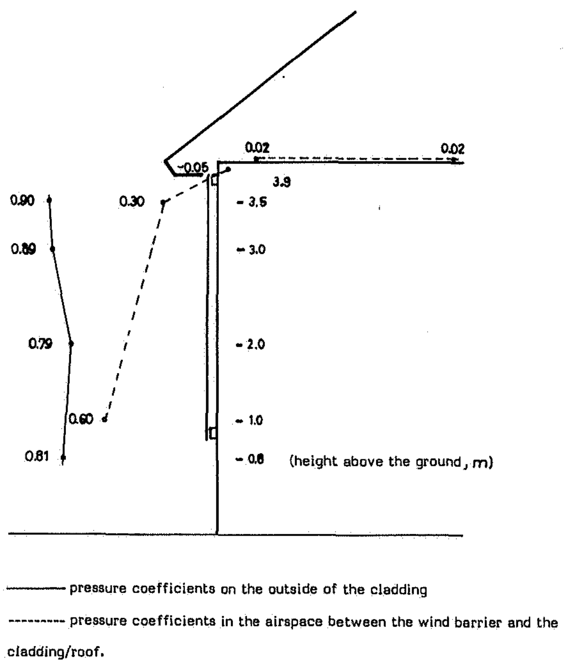

Figure 2: Example of measured wind pressure distribution at the middle of the long wall. Same construction as in Figure 1. Mean wind speed at 10 m: 15 m/s, approach angle: 0° (normal to the wall).

Calculations

The theoretical studies, as well as the experimental investigations in the hot-box, have been restricted to one specific type of forced convection in the thermal insulation, i.e. the interchange of air between the insulation and the airspace between the wind barrier and the outer cladding. This interchange of air is caused by wind induced pressure gradients in the airspace, which normally has small openings at the top and bottom for moisture evacuation. In the mathematical model, based on references 2 and 3, the inside of the wall is assumed to be airtight so that there is no airflow through the structure.

Main parameters affecting this type of heat loss are pressure gradient in the airspace, air permeance of the wind barrier and permeability of the insulation. The computer program is used to estimate the pressure gradient in the airspace, the airflow in the insulation and the resulting heat loss through the wall. The results show the importance of protecting the insulation layer with a wind barrier to achieve full effect of the insulation in wind exposed structures. For wind barriers used in Norway, like asphalt impregnated porous fibreboard, gypsum board and various types of paper, the theoretical model indicates that the increase in heat loss caused by this type of air infiltration is very small.

Hot-box measurements

To verify the theoretical model for the type of heat loss described previously, several hot-box measurements have been carried out on a timber frame wall of normal size. The guarded hot-box which is used measures 2.45 m x 2.45 m. The test wall was insulated by a 150 mm thick layer of mineral wool and made as airtight as possible on the warm side by use of plastic film and gypsum board. The forced convection was simulated by regulating vertical air flow in the space between the wind barrier and the outer cladding.

The test programme which is almost complete, includes heat loss measurements at various air speeds/pressure gradients without a wind barrier and with nine types of wind barriers. So far the measured increase of heat loss seems to be two to five times higher than calculated. For a wall with a wind barrier and at a pressure gradient of 10 Pa/m in the airspace, the calculated U-value increased from 0.27 W/°C m^2 to 0.35 W/°C m^2, which is an increase of 30%. The corresponding measured values were 0.28 W/°C m^2, 0.52 W/°C m^2 and 85% respectively. When the insulation was protected by various wind barriers, the corresponding calculated and measured increase of U-value were in the ranges of 4–20% and 7–35% respectively. For the construction shown in Figure 1, a pressure gradient of 10 Pa/m behind the cladding corresponds to a wind speed of between 12 m/s and 18 m/s.

A report of the project is planned for the spring of 1986.

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The analysis of single-sided ventilation measurements

P.R. Warren, Building Research Establishment, Garston, UK.

Introduction

Most discussion of infiltration and natural ventilation is concerned with situations in which the main driving mechanism is pressure difference created across the building and its components by wind or stack effect. There are, however, situations in which other wind-driven mechanisms may be more important, for instance the summer time ventilation of rooms with openable windows on one wall only when internal flow paths are restricted. For present purposes this will be termed *single-sided* ventilation.

Because of the wide range of parameters (wind speed and direction, temperature difference, position and characteristics of flow paths, building shape and location) which determine natural ventilation, obtaining useful design information from field measurements presents many problems. This note provides an approach for analysing the results of field measurements of single-sided ventilation. The background to the measurements and associated theoretical and laboratory studies of possible physical mechanisms for single-sided ventilation are presented fully elsewhere.[1,2]

Mechanisms

Stack effect

The basic mechanism of stack effect will operate equally well in a sealed as an unsealed space. However, for the purpose of analysing full-scale measurements, expressions (based upon references 1, 3 and 4) for predicting air exchange rate, Q, for two simple arrangements will be given here:

a) Two openings of equal area, A/2, separated by a height, H:

$$Q = (C_d/2).A.\sqrt{\frac{\Delta\theta\ g.H.}{\bar{\theta}}} \quad (1a)$$

b) A single rectangular opening, of open area, A, and height, h:

$$Q = (C_d/3).A.\sqrt{\frac{\Delta\theta\ g.h.}{\bar{\theta}}} \quad (1b)$$

where, C_d is a discharge coefficient, given the value 0.61 for present purposes; $\Delta\theta$ is the difference between, and $\bar{\theta}$ the mean of, internal and external air temperature; g is the acceleration due to gravity.

Wind effect

In the vicinity of any opening on the building surface the wind acts to create a surface pressure, which can be expressed in terms of a mean and time-varying component, and a local air velocity. Close to the surface but out of the immediate boundary layer, the latter may be regarded as parallel to the building surface and may be given a magnitude, U_L, and direction, in a plane parallel to the wall, of ß.

Single-sided ventilation is dependent in the first instance on the effect of the wind *at the opening only,* unlike cross-ventilation which, because of the internally connected flow paths, is affected by the pressures generated elsewhere on the building surface. Thus in dimensionless terms, the air exchange rate, Q, generated across an opening, at a specified position on the building surface, can be expressed as follows:

$$F_L = (Q.A./U_L) = f[Re_1, ß, (\text{window geometry})] \quad (2)$$

where f[ ] is used here, and in following equations to represent an unspecified function of the variables contained by the brackets; Re_1 is a Reynolds Number based upon a typical dimension of the opening. The dimensionless flow rate, F_L, is related to the factors which determine the general flow around the building through U_L and ß only. These, in turn, may be represented, *for any specific building,* by the following general expressions:

$$(U_L/U_R) = f[Re_2, \gamma] \quad (3)$$

and,

$$ß = f[Re_2, \gamma] \quad (4)$$

where U_R is a reference wind velocity, measured in the undisturbed wind, usually either at a height equivalent to that of the building or at a standard height for meteorological records; γ is the wind direction; Re_2 is a Reynolds Number based upon a typical dimension of the building. Comparison between wind tunnel models and full scale measurements made in the context of wind loading studies indicates that the influence of this parameter is negligible, provided that the building has sharp corners. Thus, for any given building, U_L and ß are functions of position on the building surface and wind direction, γ, only.

Equation (3) enables a second definition of dimensionless flow rate, F_R, where this is defined as:

$$F_R = (Q/AU_R) = f[\gamma] \quad (5)$$

Combined stack and wind effect

In practice, wind and stack effect will occur simultaneously. This may be accommodated in the dimensional analysis by including the dimensionless Archimedes Number, Ar, defined as $(\Delta\theta.g.H/\bar{\theta}U^2)$. U may be either the local velocity, U_L, (giving Ar_L), or the reference velocity, U_R, (giving Ar_R). Thus, for example, equation (5) becomes:

$$F_R = f[\gamma, Ar_R] \quad (6)$$

Analysis of Field Measurements

The field measurements

Measurements of single-sided ventilation have been made in two buildings; Building 1 – a simple, single-storey, experimental building containing a number of rooms with different window types, and Building 2 – a four storey school building, with classrooms either side of a spinal corridor. In each case the room under test was sealed from the remainder of the building to eliminate cross ventilation and measurements were made with different window opening arrangements, using conventional tracer gas decay methods. Simultaneously with the tracer gas measurements, measurements of U_R and γ were made at an appropriate nearby site and internal and external air temperatures were recorded. Measurements were made using both sliding windows and side-mounted casement windows, covering a range of degrees of opening and combinations of windows. The results are fully described in references (1) and (2). In order to illustrate the application of the preceding analysis only the results for simple sliding windows will be discussed here.

Building 1

The first step in analysing the measured ventilation rates is to separate out those which are dominated by stack effect. This may be done by plotting the results in the form

F_R v. $\sqrt{Ar_R}$,

following equation (6). Figure 1a shows results for a vertical sliding window, arranged with a top and bottom opening each of 0.075 m², separated by 1.16 m. For large Ar_R stack effect will dominate and the measured values of F_R would be expected to approach an asymptote represented by:

$$F_R = (0.305)\sqrt{Ar_R} \quad (7)$$

which is equivalent to equation (1a). Thus, in order to isolate results attributable largely to wind effect, points lying along or close to this line are discarded. The remaining points are

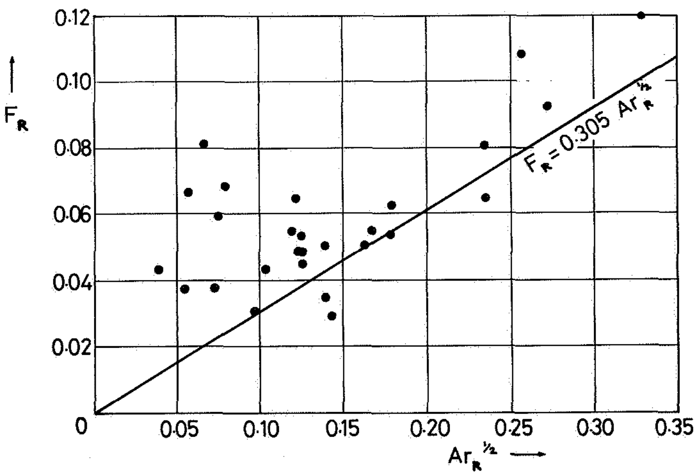

Figure 1a. Dimensionless air exchange rate, F_R versus Archimedes No., Ar – Building 1, vertical sliding window, ***all results***

plotted, in the form F_R against Υ, following equation (5), in Figure 1b. Note that Υ equals 0 for a wind direction perpendicular to the wall containing the window. Although the results are not uniformly distributed it may be seen that the values of F_R are higher with the wind directed to the window wall than when the latter is on the lee side of the building. Similar results were found for a sliding window with a single opening.[1]

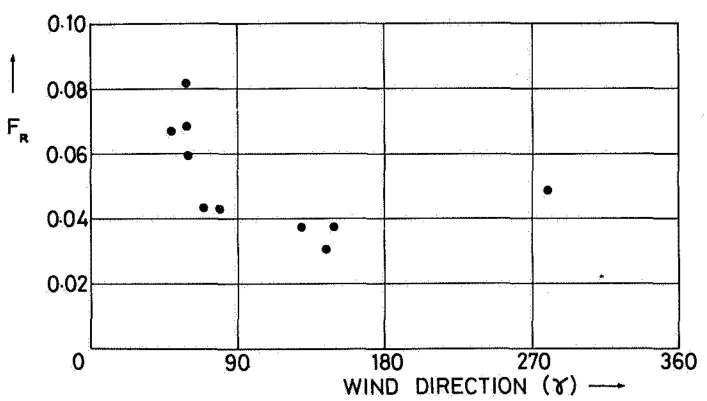

Figure 1b. Dimensionless air exchange rate, F_R, versus wind direction, Υ – Building 1, vertical sliding window, ***wind-dominated results only.***

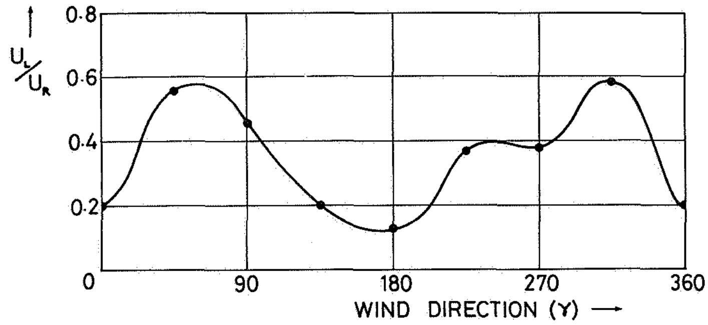

Figure 1c. Local wind speed ratio (U_L/U_R) versus wind direction, Υ – Building 1, at the surface position of the sliding window.

In order to take the further step of determining the local dimensionless flow rate, F_L, it is necessary to determine a relationship of the type defined by equations (2) and (3). This was done experimentally using a 1:25 scale wind tunnel model. Wind speed and wind direction in the local flow at the position of the window were measured using a hot wire anemometer and wool tuft respectively. The results for $(U_L/U_R)\Upsilon$. are shown in Figure 1c. Using this the value of F_L can be calculated for each measurement. In the case of sliding openings the residual effect of ß was found to be small and the mean value of F_L for the results shown was found to be 0.115 (N = 10; S.D. = 0.025). A similar value, of 0.105 (N = 23; S.D. = 0.030), was found for the single plane opening. This agrees well with limited results obtained from laboratory measurements described by Brown and Solvason.[3]

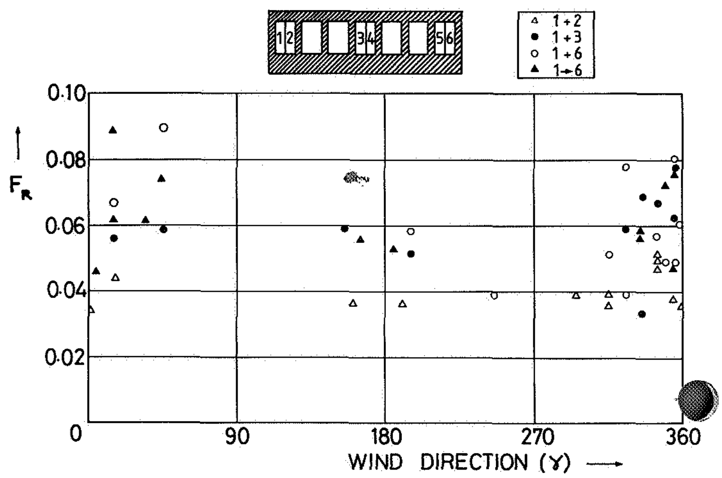

Figure 2. Dimensionless air exchange rate, F_R, versus wind direction, Υ – Building 2, vertical sliding window, wind-dominated results only.

Building 2

A similar analysis was performed on the measurements from Building 2 in order to isolate those results attributable to wind effect alone. These are shown in Figure 2 for a room fitted with vertical sliding windows. Different window combinations were used, as indicated. Again it is notable that higher dimensionless exchange rates occur when the wall containing the windows is on the windward rather than the leeward side of the building. It was not possible to model Building 2 in the wind tunnel and hence to determine (U_L/U_R) and Υ as functions of wind direction. However limited wind tunnel tests on simple building shapes[1,5] indicate that U_L/U_R (where U_R is measured in the free wind at a height equal to the building) is likely to lie in the range 0.25 to 1.0, with the lowest value on the leeward side and with highest values with the wind at an acute angle to a windward wall. Taking account of building height, the results for Building 2 are consistent with the value of 0.1 for F_L, found for Building 1.

Conclusions

Results for sliding windows from two different buildings have been used to illustrate a method for analysing the tracer gas measurements of single-sided ventilation. These indicate a simple formula for estimating the magnitude of single-sided ventilation due to wind:

$$Q = (0.1).A.U_L \quad (8)$$

Since U_L varies with position this may be simplified further for design purposes, by taking a minimum expected ratio for (U_L/U_R) of 0.25, to give:

$$Q = (0.025).A.U_R \quad (9)$$

where U_R is the design wind speed (in the undisturbed wind at the height of the building) obtained from standard meteorological data. Similar, and consistent, results based upon full-scale and wind tunnel studies for side-mounted casement windows are given in references (1) and (2).

Acknowledgements

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Report on the Air Infiltration Session at the ASHRAE, DOE, BTECC Meeting held at Clearwater Beach, Florida, USA on 2–5 December 1985

D.T. Harrje, Princeton University, USA

An air infiltration session was part of the Thermal Performance of Exterior Envelopes of Buildings III conference held at Clearwater Beach, Florida, December 2 – 5, 1985. The conference, which follows a three-year cycle, was sponsored by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, the US Department of Energy, and the Building Thermal Envelope Coordinating Council. The air infiltration session was chaired by Prof. David Claridge, University of Colorado, Civil Environmental and Architectural Campus at Boulder.

The air infiltration papers covered a variety of topics and the first paper in the session, 'The Airtightness of Office Building Envelopes' by A.K. Persily, and R.A. Grot, National Bureau of Standards, Gaithersburg, Maryland, discussed the airtightness of modern US office buildings in relation to energy use and indoor air quality. Pressurization measurements of airtightness, and tracer gas techniques to evaluate air infiltration were used together with a sophisticated, multizone computer simulation of the building. The goal was to predict infiltration from pressurization test results. Component influences in the ventilation system, such as pressure drop through ceiling vents, proved to be important to system balance and whether infiltration was controlled by pressurization of the building. Flow of air between floors was another important ingredient. Other points covered in the paper dealt with thermal loads due to infiltration during unoccupied periods and the influence on indoor air quality.

The second paper 'Seasonal Variations in Effective Leakage Area' by J.B. Dickinson and H.E. Feustel, Lawrence Berkeley Laboratory, University of California, Berkeley, concentrated on a sampling of west coast homes in a variety of yearly weather cycles. The ten occupied homes were monitored over a ten-month period using repeated fan pressurization tests. The test houses were located in Reno, Nevada (semi-arid, high desert) Truckee, California (alpine, mountainous) and San Francisco Bay area (temperate, coastal). All houses were of wood frame construction and ranged in age from one to 70 years. Temperature measurements indoors and out, windspeed, and moisture content of the indoor air and wood frame members were used in the comparisons. Noticeable seasonal variations in air leakage rate were not observed in the majority of these houses, in contrast to previous studies in higher moisture environments, in which the weather covered a wider range of absolute relative humidity.

The third paper, 'Constant Concentration Infiltration Measurement Technique: An Analysis of Its Accuracy and Field Measurements' by D.L. Bohac, D.T. Harrje and L.K. Norford, CEES, Princeton University, Princeton, New Jersey, focused on the instrumentation aspects of air infiltration measurement. This paper concentrated on the control methods used to calculate the required injection rates for the tracer gas to maintain gas concentration in a narrow band for a constant concentration tracer gas system using SF_6. The analysis was performed using state-space techniques and made use of digital computer simulations. Performance was improved by the use of a Kalman filter to estimate the tracer concentration, and a least squares estimation of the air infiltration flows. The best control and estimation method was then chosen. The accuracy of the system was verified in a series of tests in a controlled infiltration chamber in the laboratory. Field testing of the operational system in a six-zone research house demonstrated the ability of the constant concentration tracer gas to maintain the desired tracer gas concentration in all zones. The air exchange measurements compared favourably with previously conducted, extensive tracer decay measurements. The constant concentration method points out large variations in air infiltration rates between zones affected by outside temperature and wind conditions with direct implications on the inability of certain zones to meet minimum ventilation requirements.

Paper four, 'Energy Consumption Due to Air Infiltration' by G. Anderlind, Gulfiber AB, Billesholm, Sweden, focused on the question of just how much energy loss is traceable to air infiltration. The entry of air into the building via large openings was contrasted with entry via small cracks. One entry was viewed as concentrated air infiltration, the other as diffuse air infiltration. A reduction factor, R, was presented that adjusts the anticipated energy losses. The argument is that if air infiltration is totally diffuse, $R = 0$. This would indicate that the incoming infiltration is picking up the heat loss via conduction and therefore represents no additional energy loss. The author pointed out that a mix between diffuse and concentrated air infiltration actually takes place with $R > 0$ but < 1, and that this factor should be taken into account in any energy analysis, e.g., estimation of retrofit savings.

Paper five, 'Single-Sided Ventilation Through Open Windows' by P.R. Warren and L.M. Parkins, Building Research Establishment, Garston, England, dealt with the largest openings in the building envelope. Window openings not only provide summer cooling but are a common, though not recommended, practice to control interior temperatures in poorly controlled buildings. When internal doors remain closed, single-sided ventilation through windows is common in apartment buildings, schools, and offices. Using wind tunnel studies, theoretical modelling and tracer gas measurements in actual buildings, the authors point out relationships between window opening and achieved ventilation rates for a variety of common window types.

The sixth paper, 'Measurements of Wind Shelter Effects on Air Infiltration' by D.J. Wilson and J.D. Dale, Department of Mechanical Engineering, University of Alberta, Edmonton, Canada, examined the question, can varying wind shelter be neglected for residential air infiltration in cold climates? Six unoccupied test houses with varying levels of leakage air and insulation levels were used in the study. A constant concentration SF_6 tracer gas system provided more than 14,000 hours of useful data (beginning in 1982). The houses were built in an east-west row on wind-exposed farm land; thus, depending on wind direction, adjacent houses could provide wind shelter. Simple infiltration models were used in the comparisons of wind shelter coefficients. Only small variations in total infiltration rate and exposure coefficients were observed with varying wind direction. Both the non-directional effects of temperature-driven infiltration and the influence of the furnace flue were identified as the major causes for air infiltration thereby reducing the importance of wind shelter effect.

The final paper 'Case Studies of Air Leakage Effects in the Operation of High-Rise Buildings' by J.R. Wallace of Wallace Thermographics Company, Richmond, Virginia, again focused on the air infiltration problems in large buildings. Stack effect can become truly dominant in the high-rise building. Diagnostic methods, including infrared scanning and smoke sticks, were used to seek out the location of the neutral level in each building. Buildings with severe energy use and local comfort problems experienced neutral planes greatly displaced from the midheight of the building. Vertical pathways in the building structure aided the excessive stack flows and air infiltration losses. Case studies were described that pointed out typical problems and possible solutions.

These papers will be part of the Proceedings of the Thermal Performance of the Exterior Envelopes of Buildings III Conference and should be available by mid-1986 through ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA, 30329, USA.

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1986 Survey of Current Research into Air Infiltration and Related Air Quality Problems in Buildings

The AIC is currently updating its worldwide survey of current research. Nearly 900 survey forms have so far been sent out to organisations in 27 countries. If you have not received a survey form but would like a summary of your research included in this year's report, please contact Martin Liddament at the Air Infiltration Centre.

7th AIC Conference
'Occupant Interaction with Ventilation Systems'

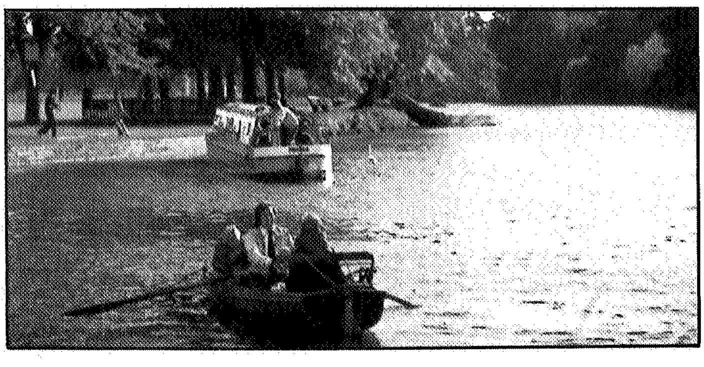
29 September – 2 October 1986
Moat House International Hotel, Stratford-upon-Avon, UK

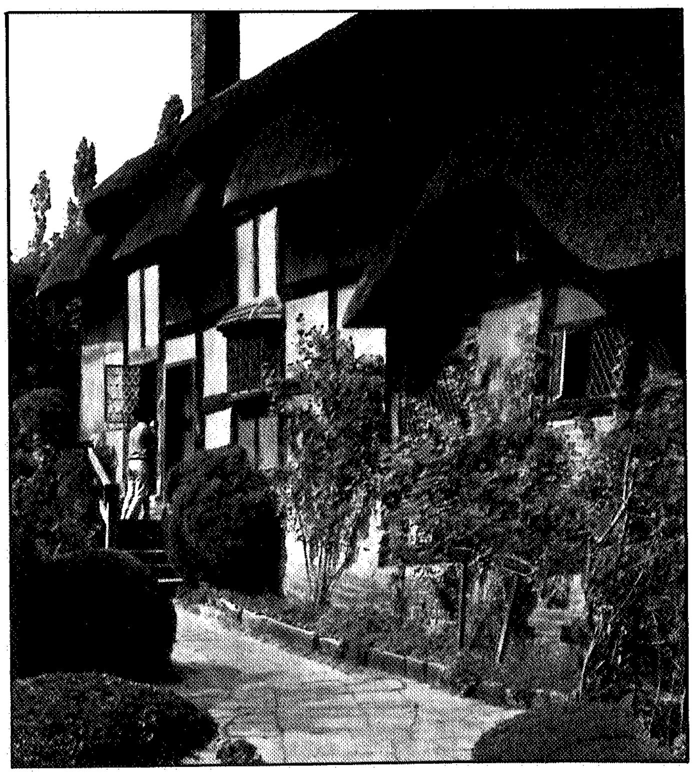
Preliminary Notice

Occupants can have a dramatic effect on building ventilation performance, and this has important energy and indoor air quality implications. 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 occupant's 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

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, 29 September – 2 October 1986, in your diary.





Some of Stratford's many places of interest:
Top left: Shakespeare's birthplace.
Bottom left: Boating on the River Avon.
Top right: Anne Hathaway's Cottage.

Book Review

Indoor Air Quality, Infiltration and Ventilation in Residential Buildings

Prepared by W.S. Fleming and Associates Inc., USA for the New York State Energy Research and Development Authority, and the Niagara Mohawk Power Corporation, USA.

Introduction

The primary concern of this research project was to investigate the relationship between the tightness/infiltration characteristics and indoor pollution levels of housing. Five common pollutants were studied in particular: *radon, nitrogen dioxide, formaldehyde, respirable* suspended particulates and carbon monoxide. Those pollutants whose concentrations were found to be above accepted American pollution standards were candidates for further study and/or testing for various control techniques.

The project was divided into three phases:

- an initial survey
- follow-up monitoring in houses with high indoor pollution levels
- evaluation of permanent control techniques.

Sixty, mainly new houses of varying construction practices and locations in New York State were studied initially. Pressurization tests were made and detailed information on infiltration sites and possible sources of indoor pollution obtained. Radon concentrations in soil, water and indoor air were monitored and information on bedrock geology and soil types was obtained from maps. Thirty of the houses were also monitored for air exchange rates, combustion pollution and formaldehyde for at least a one-week period. Indoor combustion sources included unvented kerosene heaters, gas ranges, wood and coal-burning stoves and fireplaces, gas and oil-furnaces, and smokers.

Six houses with high indoor combustion pollution levels were each continuously monitored for periods ranging from two to five weeks.

Permanent indoor pollution control techniques were fitted in six houses with high combustion levels and 14 houses with high radon levels, and their effectiveness monitored for an extended period (two to three weeks for combustion pollution, one to two weeks for radon).

Results

The distribution of the various pollutants over the sources are detailed. For a specific house with a constant indoor pollution source, decreased air exchange rate increased indoor air pollution levels. However, the tightest houses in the study did not necessarily have the highest pollution levels. In general, indoor air pollution levels were related more to pollution source strength than to house tightness.

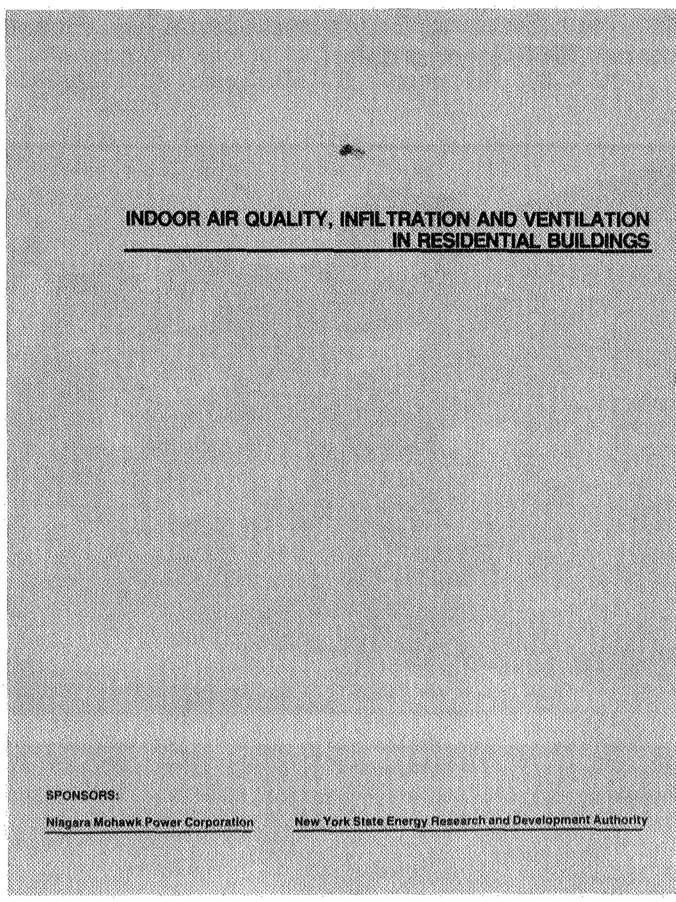
Prevention of pollution proved more effective than control. However, if the sources could not be avoided, their effect could be reduced by local ventilation at the source, filtration, and/or increased whole house ventilation if the pollution source strength was relatively low and diffuse.

Various control strategies are suggested for the individual pollutants. Construction practices to achieve energy efficiency and low indoor pollution are detailed and typical specific leakage sites pointed out. Windows, doors and fans must be carefully situated and central air-to-air heat exchangers can be employed if a house is very tightly constructed.

Of the four infiltration models used, the model developed by the Lawrence Berkeley Laboratory seemed to provide the most consistent results for a variety of houses under different terrain and shielding conditions.

Conclusions

This research project and others have demonstrated that indoor air pollution problems may be more widespread than initially thought. Increased use of alternative heating appliances, synthetic building products and furnishings, and reduced infiltration and ventilation may exacerbate the situation in future.



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New Publications

AIC-TN-18-86
A Subject Analysis of the AIC's Bibliographic Database – *AIRBASE* (4th Edition)

The fourth subject analysis of *AIRBASE* is now available. It contains a full subject description of almost 2,000 scientific and technical papers on air infiltration and related topics. Full bibliographic details are given for each entry.

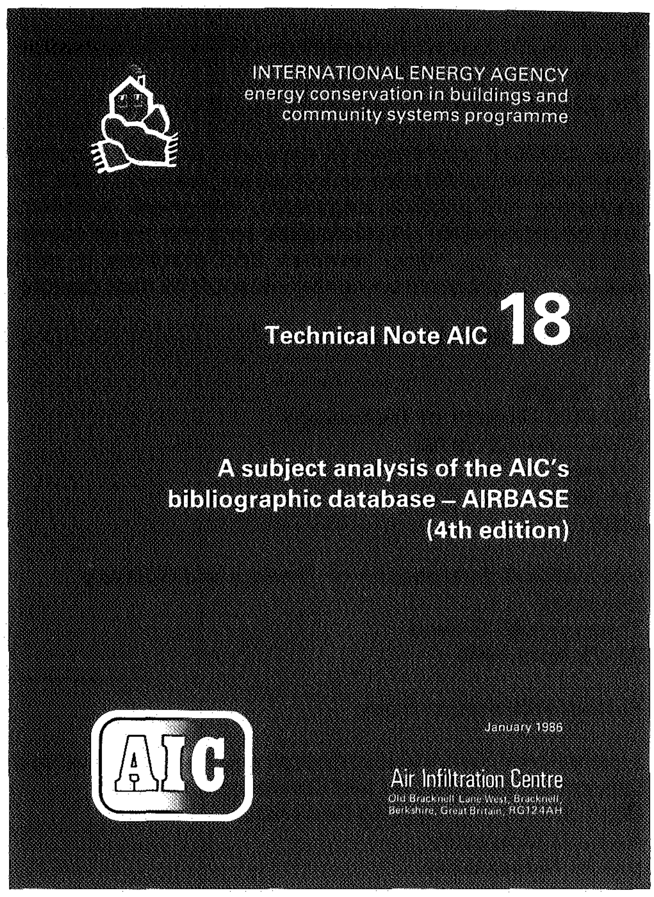
The subject description is broken down into 14 main areas:

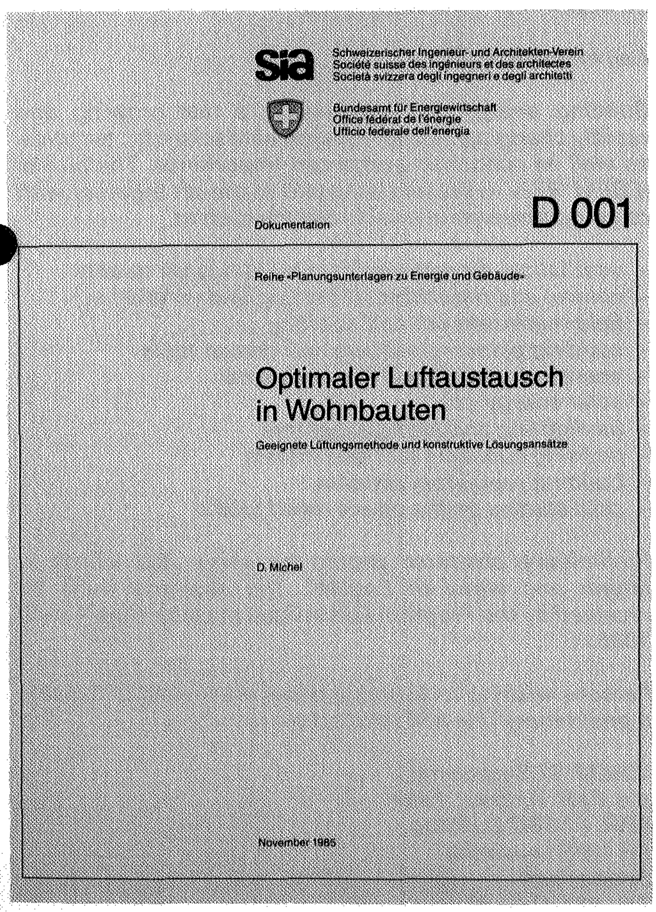
1. Tracer gases
2. Tracer gas measurements by type of buildings
3. Tracer gas methods
4. Pressure tests of leakage of components
5. Pressure tests of leakage of buildings
6. Surface pressures on buildings
7. Theoretical models
8. Reduction of heat losses
9. Energy and buildings
10. Pollution, air quality and indoor climate
11. Moisture and humidity
12. Occupancy effects
13. Instrumentation and measurement techniques
14. Miscellaneous

and then further subdivided within each section. An index of principal authors is also included.

This report thus provides an up-to-date and comprehensive guide to air infiltration literature and will undoubtedly be a valuable reference tool for all those interested in this area of reseach. Copies of the articles referenced are usually available direct from the AIC library.

Available free-of-charge to organisations in participating countries only.*





Optimaler Luftaustausch in Wohnbauten
Geeignete Lüftungsmethode und konstruktive Lösungsansätze

by D. Michel, Swiss Association of Engineers and Architects
SIA Dokumentation D 001 in the series 'Planungsunterlagen zu Energie und Gebäude'

This is a selected translation of Air Infiltration Control in Housing – A Guide to International Practice, emphasising the aspects that are most relevant to Swiss requirements.

It describes the criteria for obtaining an optimum air change rate, measurement methods for air infiltration and air leakage, ventilation strategies, construction principles for airtightness and retrofitting.

Definitions of air infiltration terminology are given and an extensive bibliography of useful literature is appended.

Copies of this publication are available from:

SIA
Schweizerischer Ingenieur- und Architekten-Verein
Postfach
CH 8039 Zurich
Switzerland
Tel: 01/201 15 70

Price: 30 SFr

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Forthcoming Conferences

1. IAQ '86
Managing Indoor Air for Health and Energy Conservation
Atlanta, Georgia, USA
20–23 April 1986

This *ASHRAE* conference is expected to be the premier international conference on indoor air quality in 1986. The gathering will provide engineers, designers, architects and environmental physiologists with the most current information regarding research and practices in what may well be the environmental issue of the next decade.

Further information from:

J.R. Wright
ASHRAE Director of Technology
1791 Tullie Circle NE
Atlanta
GA 30329
USA

2. International Symposium on 'Energy and Building Envelope'
Thessaloniki, Greece
22–25 April 1986

Further information from:

International Symposium: Energy and Building Envelope
Laboratory for Building and Construction Physics
Dept. of Civil Engineering Secretariat
Aristotle University
546 36 Thessaloniki
Greece

3. 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

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

Topics:

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

5. 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

6. 7th AIC Conference
Occupant interaction with ventilation systems
England
29 September – 2 October 1986

Further details from:

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Berkshire
RG12 4AH
Great Britain
Tel: +44 344 53123
Telex: 828488 BSRIAC G

7. 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
Germany
Tel: (030) 305 31 31
Telex: 186 11 cpo d

8. 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.

Persons wishing to submit a paper are invited to indicate a preliminary title and return it to:

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

AIC 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 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'
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 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 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.
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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'
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.
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.
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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).

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'.
  5th 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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