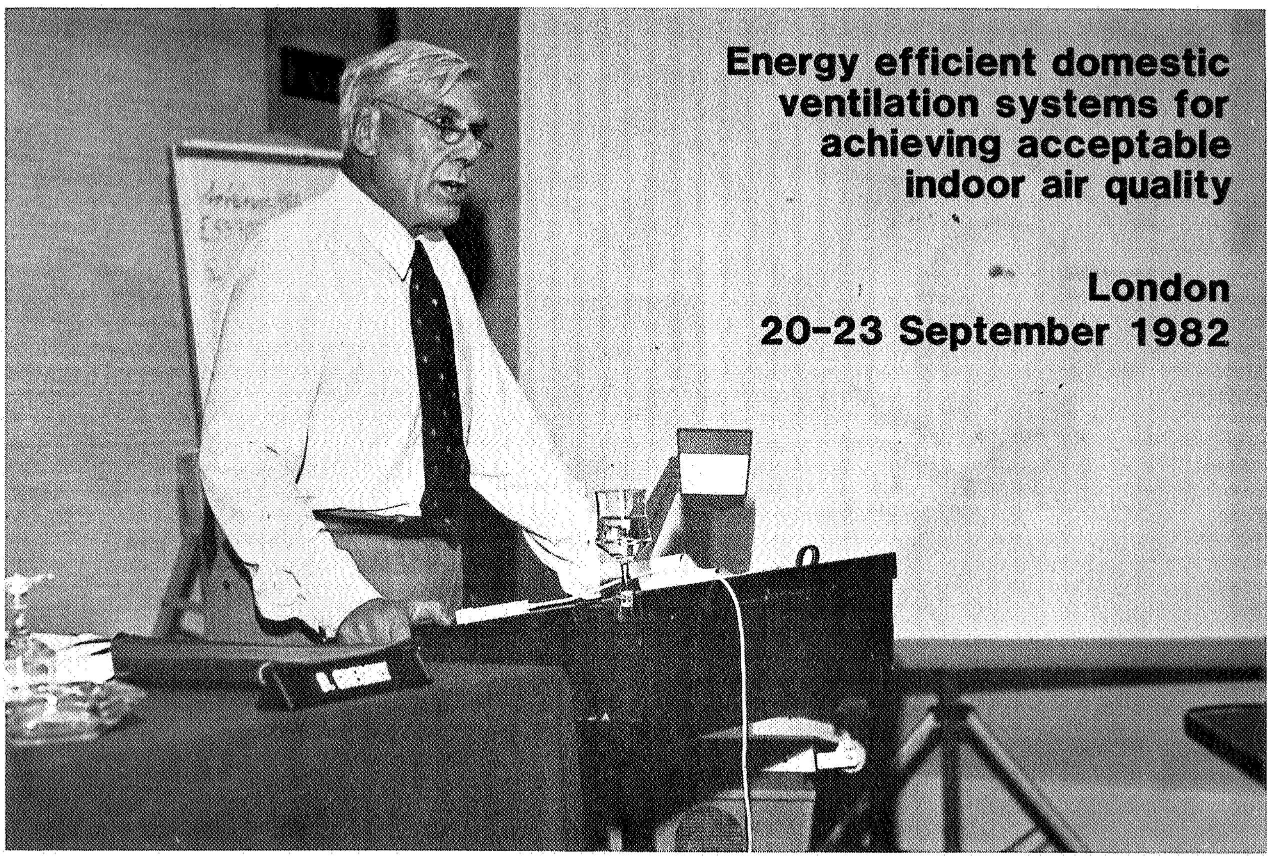
Air Infiltration Review

a quarterly newsletter from the IEA Air Infiltration Centre

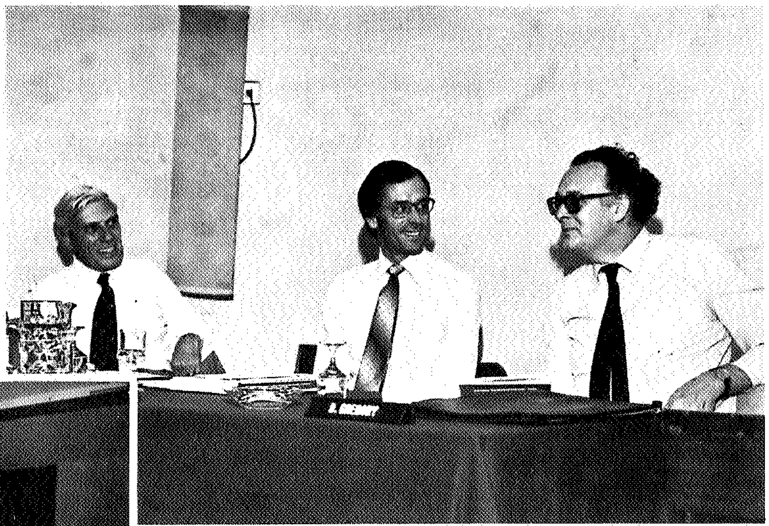
Vol. 4, No. 1, November 1982

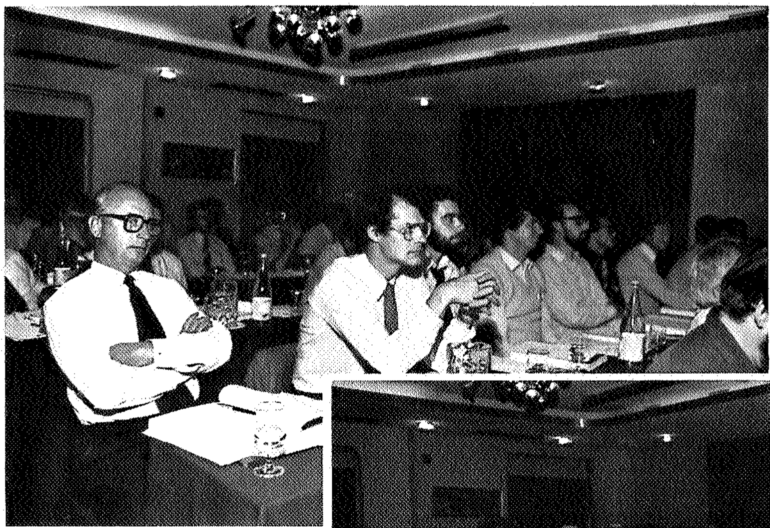
AIC's Third Conference

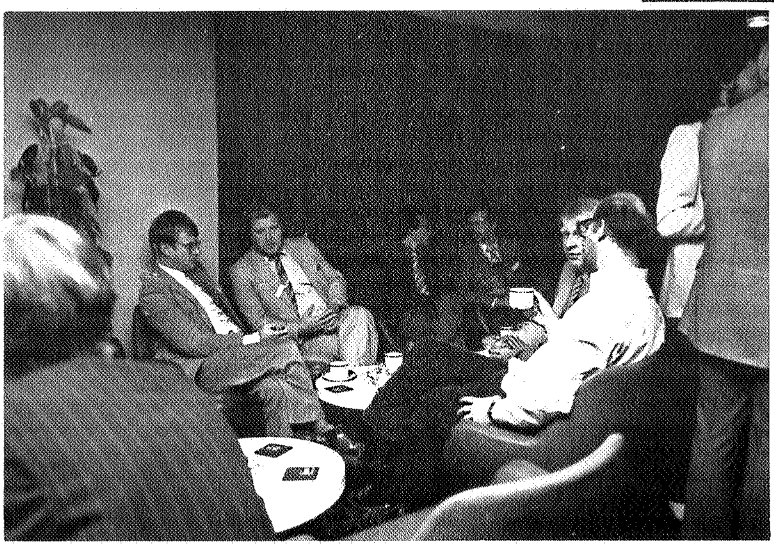


Mr. Neville Billington, OBE presenting his Keynote Paper "The Art of Ventilation"

THIS issue also includes articles on Ventilation through open windows (p4) Indoor air quality (p6) and Ventilation rate measurement (p8) . . . read on







Conference Report

Energy Efficient Domestic Ventilation Systems for Achieving Acceptable Indoor Air Quality

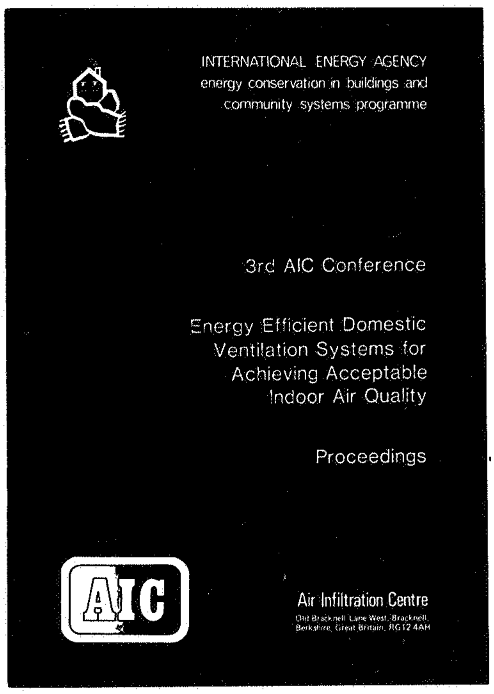
The Air Infiltration Centre's 3rd Annual Conference provided an ideal opportunity for researchers and designers to interchange ideas on recent developments in energy efficient domestic ventilation. Delegates from all participating countries attended and, by invitation, there were also speakers from France, Germany and the Republic of Ireland.

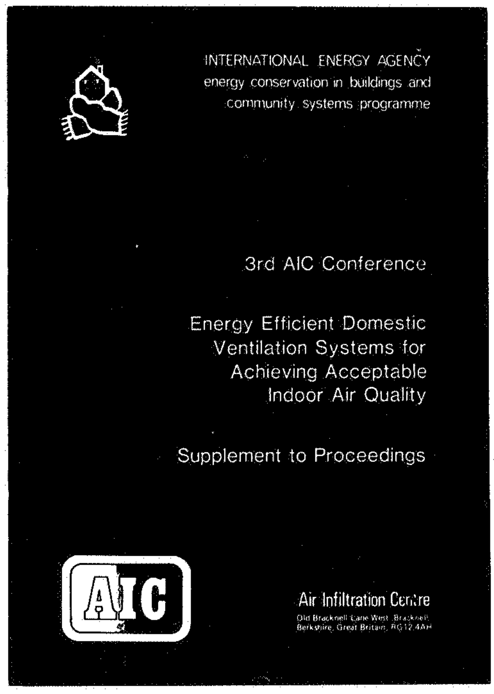
The Conference was formally opened by Dr Derek Gregory, director of Building Services Research and Information Association (BSRIA) – home of the Air Infiltration Centre. In his welcoming address, Dr Gregory emphasised the importance of international co-operation and described BSRIA's role in the operation of the Centre.

The keynote paper was presented by Neville Billington, OBE, BSRIA's first director. His contribution entitled 'The art of ventilation' took a fascinating historical look at the needs for ventilation and the methods developed to meet them.

Optimism was expressed at the Conference that significant progress has been made in understanding both the complexities of air infiltration and its importance in relation to the control of ventilation. In particular, it was pleasing to note that many of the contributors described the results of case studies. Papers on window opening, air quality, moisture control, passive and mechanical design strategies, ventilation efficiency and theoretical approaches served to provide a balanced content to the meeting. In addition, a discussion session on the relative merits of passive and mechanical ventilation systems provoked lively debate.

The Conference closed with a visit to the British Gas Research and Development Division, Watson House, London where delegates had the opportunity to see at first hand the wide range of ventilation research projects taking place there.





The printed conference proceedings contain 23 papers, many of which provide details and operating experiences of a wide variety of design solutions. Techniques described range in complexity from the use of strategically placed slot air vents to the installation of balanced mechanical ventilation systems incorporating air-to-air heat recovery. Other papers discuss user reactions and the influence of ventilation methods on indoor air quality. Thus these proceedings give comprehensive coverage of various approaches to the design and application of energy efficient domestic ventilation systems.

The proceedings are available price £17 sterling including post and packing direct from the Air Infiltration Centre.

A supplement to the proceedings containing a record of the discussions and five additional papers is being produced. This will be supplied free-of-charge to the Conference delegates, and will be available shortly to others at a price of £6.50 sterling including packing and postage.

Orders for these publications should be sent direct to the AIC using the form on page 11.

Ventilation Rates and Energy Consumption due to Open Windows. A Brief Overview of Research in the Netherlands.

Willem de Gids and Hans Phaff
Institute for Environmental Hygiene-TNO, Delft, Netherlands

Introduction

Open windows and energy consumption is nowadays one of the main topics in ventilation research. The problem can be divided in two parts:

- How do people use windows?
- How effective are open windows in terms of influencing air change rates?

Both questions cannot be answered clearly. The available knowledge is insufficient.

Behaviour

In the Netherlands, inquiries have been carried out in about 1500 dwellings to study window opening behaviour[1,2]. The most important results of this study are summarized in Table 1.

From the figures in Table 1, it can be seen that there are three groups:

- A group that frequently opens vent lights, grilles or casement windows.
- A group that rarely opens vent lights or casement windows.
- A group with medium use of both types of windows.

An interesting question here is whether there is any relation between the use of windows and the airtightness of dwellings. With respect to window opening behaviour, a lot of questions still remain and hopefully some of them will be answered in the IEA annex VIII 'Inhabitants' behaviour with regard to ventilation'[3]. This study begins this year and the participating countries are Belgium, Germany and the Netherlands.

Air Change Rates Through Open Windows

The air change resulting from opening a window in a room with the internal door shut has been the subject of investigation[4,5,6] (see Figure 1).

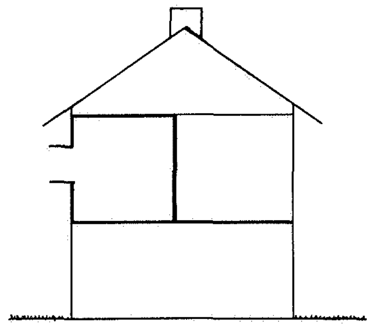


Figure 1. What is the air change rate of a room with an open window under different meteorological conditions?

One can imagine that there have to be flow patterns through an open window as illustrated in Figure 2.

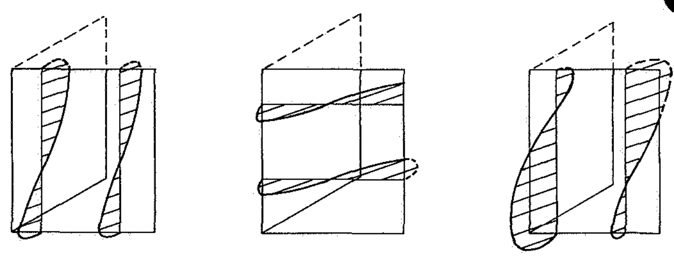


Figure 2. Flow patterns through open windows.

In our investigation[6], measurements have been carried out at three locations, all on the first floor of a building situated in an urban environment and surrounded by buildings up to 4 floors high. The measurements consisted of:

- External, window and room air velocities.
- Air change rate.
- Temperature.

In total 33 measurements were made.

TABLE 1: Results of opening windows and grilles for ventilation.

		Vent light or ventilation grille				
		Always open	Sometimes open	Never open	No answer	Total
Casement Windows	Daily (some hours open)	16,6%	11,4%	12,5%	0,6%	41,1%
	Daily (one hour or less) + weekly (some hours)	11,6%	12,2%	12,1%	0,1%	36,0%
	A few times weekly (one hour or less)	6,9%	6,5%	8,7%	0,1%	22,2%
	No answer	0,2%	0,1%	0,3%	0,2%	0,7%
	Total	33,4%	30,2%	33,5%	0,9%	100%

The influence of various window types (vertically pivoted casement windows, horizontally pivoted vent lights and a sash window) and of window height/width ratios on air change rate was investigated, but no clear distinctions could be made for these variables. From the air change rate measurement an effective air velocity through half of the open window area has been deduced which is defined as:

$$V\,eff = \frac{a.\,V}{\tfrac{1}{2}\,A.3600} \qquad (1)$$

in which a = measured air change rate per hour
V = volume of the room (m^3)
A = effective open area of the window (m^2)

An approximate equation for the effective air velocity through the window is given by:

$$V\,eff = \sqrt{C_1\,(V_{met})^2 + C_2.H.\Delta T + C_3}$$

in which C_1 = dimensionless coefficient depending on the wind effect
C_2 = buoyancy constant
C_3 = turbulence constant
H = height of the window
ΔT = mean temperature difference between inside and outside
V_{met} = meteorological wind velocity

From the measurements, the best fitting constants C_1, C_2 and C_3 have been deduced. An equation with which the air velocity and hence the flow rate and the air change rate can be estimated is the final result:

$$Veff = \sqrt{0{,}001\,(V_{met})^2 + 0{,}0035.H.\Delta T + 0{,}01} \qquad (2)$$

A comparison with the results of this equation and the measurements is shown in Figure 3.

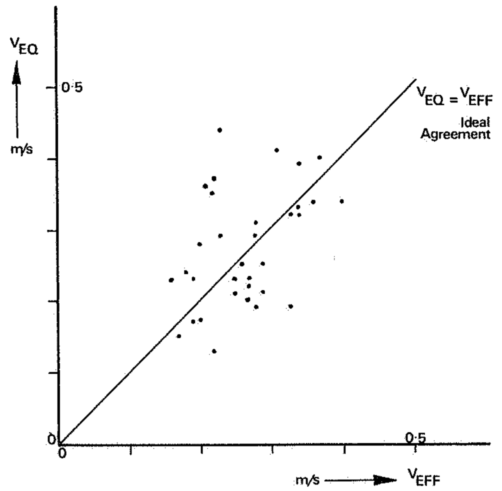


Figure 3. The 'measured' air velocity through the window (1) as a function of the calculated value from (2).

Although the scatter is rather large, in our opinion the correspondence between the measured and calculated values is reasonable.

Energy

With the previous equation (2), the air change rate can be calculated for different meteorological conditions (see Table 2).

Table 2.

Air change rate per hour				
Meteorological wind velocity (m/s)	Temperature difference (K)			
	0	5	10	15
0	3,5	6	7,5	9
2	4,5	6,5	8	9,5
5	6,5	8	9,5	10,5
8	10	11	12	13

In Table 2 the open area of the window is 0,5 m^2 and the room volume is 25 m^3.

In Table 3 an example is given of the effect on energy demand of the length of time that a window is left open. In this example, a window has been opened in two rooms. The energy consumption by infiltration and ventilation due to the two windows is given in MJ per heating season for a Dutch situation, i.e. a mean temperature difference of 15 K.

Table 3.

Windows	Energy consumption per heating season (MJ)
(a) Closed	350 . . . 2100
(b) Open for 3 hours a day	5500 . . . 6900
(c) Open for 25 minutes a day	1000 . . . 2800
Energy difference between (b) and (c)	4500 . . . 4100

The possible savings by reducing the time that windows are left open can thus be estimated and is of the order of 4300 MJ per heating season for such a dwelling.

Literature

1. VAN GUNST, E.
Ventileren door kieren of kieren afdichten?
Delft IMG-TNO publication 819, 1982.

2. NATIONALE WONINGRAAD.
Beleving en gebruik van ramen in woningen.
Almere, September 1981.

3. IEA ANNEX VIII.
Inhabitants' behaviour with regard to ventilation.
Paris, June 1982.

4. WARREN, P.R.
Ventilation through openings on one wall only.
Building Research Establishment, Department of the Environment.
August 1977.

5. COCKROFT, J.P., Robertson, P.
Ventilation of an enclosure through a single opening.
Building and Environment Vol. 11 pp 29 to 35, Pergamon Press 1976.

6. PHAFF, J.C., de Gids, W.F., Ton, J.A. et al.
Ventilatie van gebouwen. Onderzoek naar de gevolgen van het openen van een raam op het binninklimaat van een kamer.
Delft IMG-TNO rapport C448, March 1980.

Indoor Air Quality and Minimum Ventilation Rate

Dr. G. Huber and Prof. Dr. H.U. Wanner
Department of Hygiene and Ergonomics
Swiss Federal Institute of Technology
Zurich.

Introduction

Energy conservation efforts of the past ten years have directed our attention towards heat losses due to ventilation. Improved insulation of cracks and slits around doors and windows, as well as the reduced operation of forced ventilation systems wherever available, have led to reduced air exchanges and hence to a considerable reduction in the supply of fresh air. In this context, the studies on indoor air quality have become more important. From a hygienic point of view, questions are raised as to the effects of such measures on indoor environment and the minimum ventilation rates necessary in order to fulfil the hygienic requirements of indoor air quality.

In this paper, we give first a short review on the most important sources of indoor air pollutants, then the possibilities for measuring the contamination of room air by persons (carbon dioxide and odours) will be described, and finally we list some recommendations for the minimum fresh air rates. These recommendations are based on experimental investigations which are referred to in another study.[1] The most important results of this study have been integrated in the present paper.

Sources of Indoor Air Pollution

The sources of pollutants which contaminate indoor air at workplaces as well as in residential quarters can be classified into two groups, shown in Figure 1. On the one hand we have the pollutants from ambient air or outdoor air which gets indoors by natural or by forced ventilation; the main sources outdoors which can influence the quality of air indoors are streets with heavy traffic density, industries and house heating equipment. On the other hand there are some sources of air pollutants which happen to be indoors themselves. Furnishing a room and using it, plays an important role. Emission products of modern building materials demand special attention here.

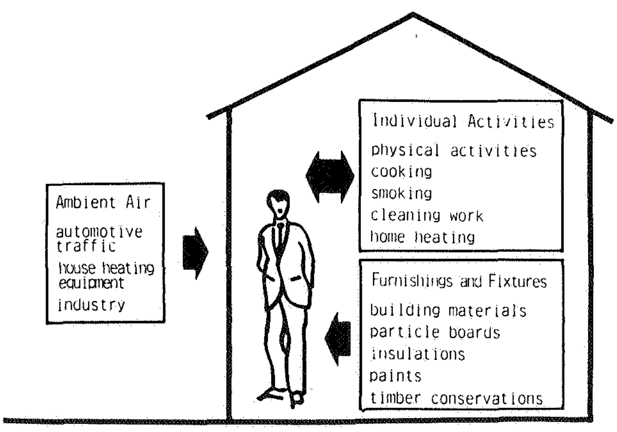


Figure 1: Sources of Indoor Air Pollution. Furnishings and fixtures could emit contaminants over a long period of time. The pollution load caused by individual activities depends on the occupancy and the use of the room. The contribution of the outdoor air depends upon the location of the building.

This article deals with the indoor air pollution caused by *man alone.* Subjectively, such pollution can best be assessed through odours and objectively by measuring the carbon dioxide in the room. Concentration of carbon dioxide in ambient air lies between 0.03 and 0.04%; this percentage can be double in cities and in industrial areas. In some European countries we have a maximum recommended level of 0.1% CO_2 in indoor air of living places (so called Pettenkofer-Number), and in some cases even 0.15% CO_2. In the USA a limit of 0.25% CO_2 is taken for general ventilation standards, leaving an additional safety factor covering individual activities, diet and health variations.[2]

Methods of Measuring Carbon Dioxide and Odour

The carbon dioxide was measured by means of an infrared gas analyzer ('URAS-2'). The evaluation of instantaneous odour was effected by sensory perception, i.e. through subjective odour intensity assessment carried out by test persons. For this purpose it was necessary to develop an apparatus capable of conveying the relatively weak odours emanated by the people in the test-room to a group of four especially selected test-persons for their assessment.

Using the glass/teflon odour intensity measuring instrument GIMA, it was possible to present not only odours from the test-room itself, but also reference odours of known Pyridine concentrations for assessment. This method made it possible to register mixed odours of unknown concentrations in a semi-quantitative manner.

Further details of the GIMA apparatus and for the determination of the odour intensity are described in full in other papers[3,1]

Tests at Standard Conditions

18 runs were made in a test-chamber of 30 m^3 volume. Each run took two hours. The odour intensity of the test-chamber was evaluated every 15 minutes. Temperature, relative humidity and carbon dioxide concentrations were monitored continuously. The variables in the test runs were number of persons (1, 2 or 4), space volume per person (30, 15 or 7.5 m^3) and air exchange rate (0.1, 0.2, 0.8 or 1.6 per hour). For each of these variables there are 2 to 3 runs (total 18).

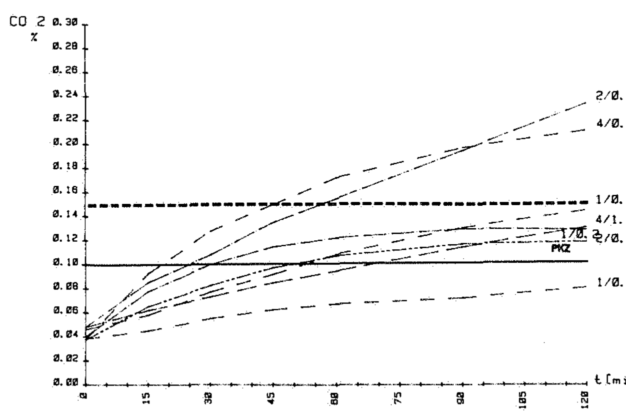


Figure 2: Duration of the carbon dioxide concentration in the room air of the test chamber. Variables: Persons (1, 2, 4) and air exchange rate per hour (0.1, 0.2, 0.8, 1.6). Each PKZ = Pettenkoferzahl of 0,1% CO_2.

The concentration of the carbon dioxide content in the air during the test runs is represented in Figure 2. The measurements were effected at the same intervals as the determination of odour annoyance (every 15 min). The curves show that carbon dioxide concentrations of 0.15% are exceeded after approximately 1 hour in 2 of the tests (2 persons, air exchange 0.2/h and 4 persons, air exchange 0.9/h).

The odour intensity assessed by test persons is shown in Figure 3. Although strong deviations occur, there is a distinct tendency which can be derived from the curves, i.e. the higher the number of persons and the smaller the air exchange rate, the stronger is the odour intensity assessed. The intensity of 80 'odour units', which has been indicated by test persons as 'acceptable', is not exceeded in the tests with 1 person alone in the climatic chamber; with 2 and 4 persons respectively, this threshold is exceeded after 60–90 minutes.

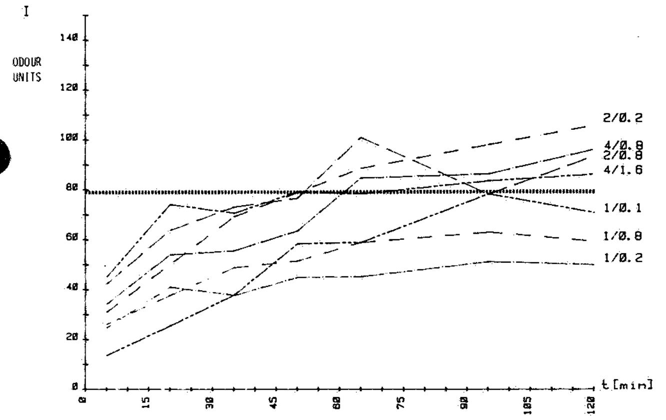


Figure 3: Duration of assessed odour intensity in the room air of the test chamber. The test persons evaluated the intensity of 100 'odour units' as the concentration of 365 ppb Pyridine. Odour intensities up to 80 'odour units' were assessed as 'acceptable'. Variables: Persons (1, 2, 4) and air exchange rates per hour (0.2,/.4,/.8, 1.6). Each curve is an average value of 2–3 runs.

The comparison of the curve relating to the odour intensity with that of carbon dioxide concentrations shows that there are connections between these 2 parameters. Such a relation is of a high practical value as, based on a relatively easy realisation of the carbon dioxide measurements, statements on a momentary odour situation in a room can be made.

Conclusions

Recommendations for a minimum ventilation rate or minimum fresh air supply based on this study are shown in Figure 4. The determining criterion is that the CO_2 concentration of 0.15% or the corresponding odour level of 80 odour-units should not be exceeded. Based on this curve, for a space volume of 15 m^3 per person, a minimum fresh air supply of 12 to 15 m^3 per person per hour is required. With the chosen duration of 2 hours for the tests, the 'space volume' also has an influence: at a space volume higher than 15 m^3 the fresh air supply rate will be lower and vice versa. But fresh air supply per person per hour should not be lower than 10 m^3 and the space volume per person should not be lower than 5 m^3.

For tests of a longer duration, the influence of the 'space volumes' would only be of minor importance, e.g. at an air exchange rate of 0.2/h, there will be stabilization after approximately 4 hours. However, in practice such a situation rarely occurs.

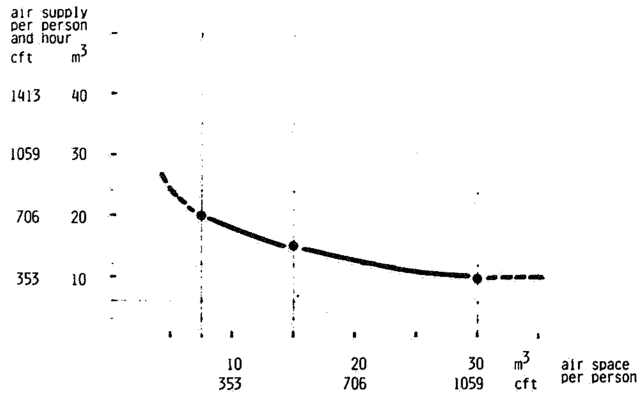


Figure 4: Minimum ventilation rates or minimum fresh air supply rates. Recommendations for a minimum ventilation rate can thus be worked out from CO_2 content of indoor air and the perceived odour intensity. The recommendations are based on values established after a test of 2 hours.

These recommendations are valid only for rooms where smoking is not permitted and where there is no other source of odour. The relationship between CO_2 and the perceived odour intensity derived in this study is not applicable for rooms where smoking is permitted. In order to ensure satisfactory air quality in such rooms one must allow for a fresh air supply of twice to four times the above-mentioned rate. Similarly the ventilation should also be increased in the rooms where work with physical activities is being done. Here the supply of fresh air should be adjusted to the demands of air quality required by the type of activities.

References

1. HUBER G.
   Minimale Lüftungsraten in Wohnund Arbeitsräumen, Dissertation Eidg. Technische Hochschule, Zürich.

2. Ventilation for Acceptable Indoor Air Quality, ASHRAE *62,* 1981.

3. HUBER G., HANGARTNER, M. and GIERER, R.
   Sensorische Geruchsmessung,
   Sozial- und Praventivmedizin, *26,* 1979–182.

Let Others Know ......

Air Infiltration Review offers the opportunity for brief, informative articles relating to air infiltration research and its application. Contributions of general interest on, for example, new projects, developments in instrumentation, novel applications of energy saving, natural or mechanical ventilation systems, or behavioural effects on infiltration would be most welcome.

Why not prepare an item for the next issue? Last date for receipt of copy is 4th January 1983.

An Automated Air Infilation Measurement System - Its Design and Capabilities - : Preliminary Experimental Results

Leif Lundin and Åke Blomsterberg
National Testing Institute, Sweden

Introduction

Air infiltration has been studied by several researchers. They have been using the decay of a tracer gas in order to measure air infiltration. This technique is used for short term measurements and cannot, without great difficulties, be used for long term measurements. It is also difficult to make accurate measurements of the ventilation rate of individual rooms.

Therefore, a completely automated constant concentration technique has been developed. This technique makes it possible to perform long term measurements simultaneously in a number of rooms.

Principle of Measurement

The most common tracer gas technique records the decay of a tracer gas. A tracer gas is injected into a room or a whole house and the decay in the concentration of the tracer gas is measured. From these measurements the air change rate is calculated directly. Continuous measurements are difficult to make. When the energy loss caused by air infiltration is to be calculated the ventilation rate must be expressed in m^3/h. To convert the results from a measurement the effective volume must be known. This is a number which is often hard to calculate accurately. The required equipment is however rather simple. The only thing needed is a tracer gas analyzer measuring differences in the tracer gas concentration.

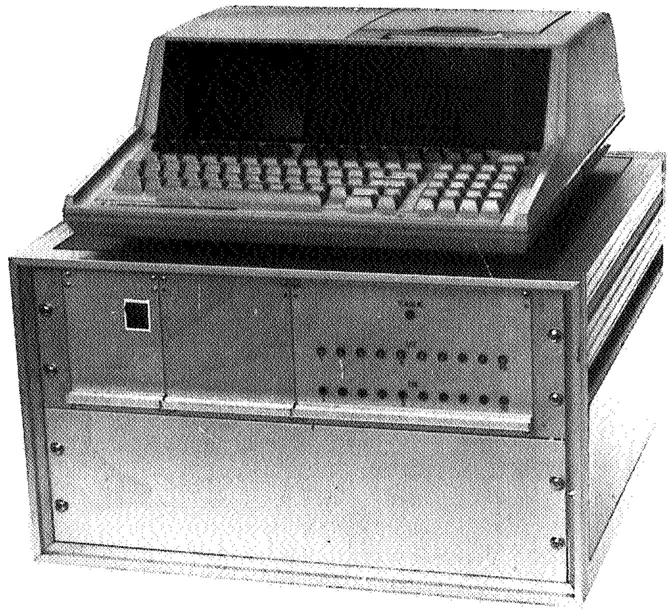


Figure 1. Controller on top of injection and sampling unit.

The automated air infiltration measurement system developed at the National Testing Institute maintains a constant concentration of a tracer gas in nine rooms simultaneously. Tracer gas is injected into each room and the concentration is measured in each room. A target concentration is maintained. The result of the measurements is the supply of fresh air to each room. The result is given in m^3/h directly without any estimation of the effective volume.

Long term measurements can be made. The technique requires accurate measurements of the absolute concentration of a tracer gas and of the tracer gas flow. The concentration must remain constant throughout the whole measuring period.

Description of Equipment

The equipment consists of five components:

1. A controller.
2. A tracer gas analyzer.
3. An injection and sampling unit.
4. Special mixing fans.
5. Apparatus for the calibration of the tracer gas flow.

The system is controlled from a Hewlett Packard 85 microcomputer (see Figure 1). The concentration of the tracer gas is kept constant using a program based on the principle of a PI-regulator. A measuring period is started with a short decay measurement. This is done in order to estimate the ventilation rate and to be able to reach the target concentration in a short time. This time is approximately 45 minutes.

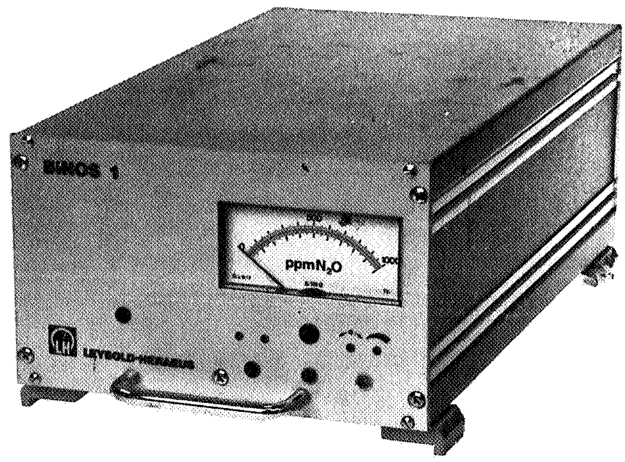


Figure 2. Tracer gas analyser.

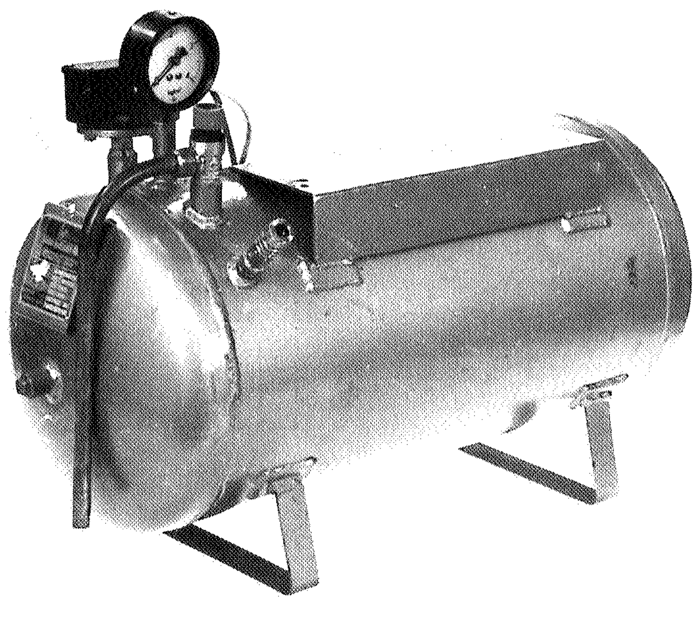


Figure 3. Tank where the pressure is kept at a constant level.

The tracer gas concentration is measured using a fast analyzer, a Binos 1 (see Figure 2). Nitrous oxide is used as the tracer gas.

A tracer gas cyclinder is connected to a tank where the pressure is kept constant at 200 kPa (see Figure 3). The tank is connected to the injection side of the injection and sampling unit (see Figure 1 and 4). This unit contains a microprocessor and solenoid valves for injection and for sampling.

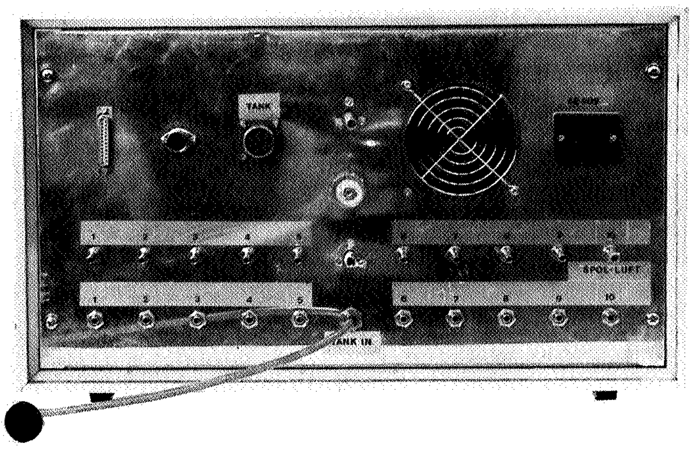


Figure 4. Injection and sampling unit.

Two plastic tubes, one for injection and one for sampling, are passed to each room to be monitored. Air in each room is sampled sequentially. The measured tracer gas concentration is used to continuously update the necessary injection rate, to maintain a constant concentration.

The current version of the apparatus maintains a constant concentration of 500 ppm which is too high for use in occupied rooms. It would be difficult to maintain a lower concentration as concentrated tracer gas is injected. Using diluted tracer gas was considered to be too expensive and would reduce the accuracy.

A special mixing fan was developed (see Figure 5). The fan is located on the floor in the middle of the room to be tested. The tracer gas enters below the fan and a gentle air flow will move the tracer gas upwards. The fan is powerful enough to mix the tracer gas, without influencing the air infiltration.

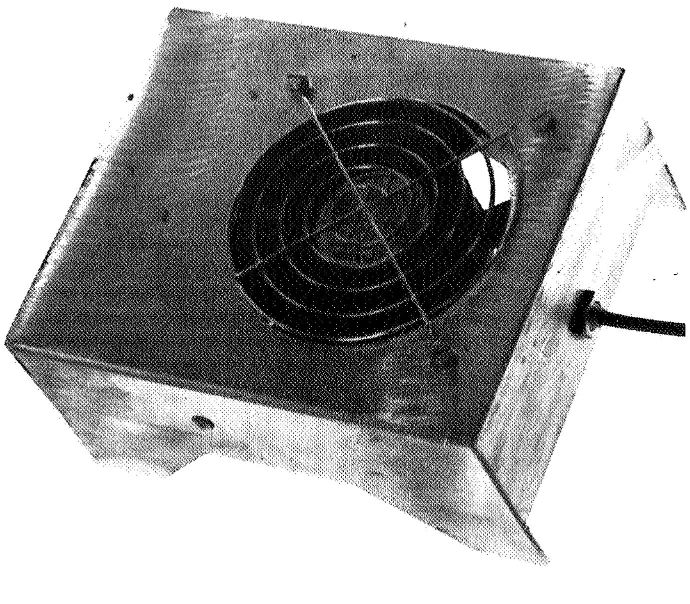


Figure 5. Special mixing fan.

A special unit for calibration of the tracer gas flow was developed. The basic principle of the unit is the principle of communicating vessels with liquid. Each plastic tube used for injection is calibrated.

The above described equipment can also be used for air infiltration measurements using a constant tracer gas flow technique or using the decay technique.

Preliminary Experimental Results

The automated air infiltration measurement system has been used in a couple of houses. In order to see how well the mixing fans work the tracer gas concentration was measured at nine different locations in a room. This was done in a one-family house with natural ventilation. The tracer gas was injected at one location. The concentration increased simultaneously at all nine locations and the target concentration was reached after 45 minutes (see Figure 6).

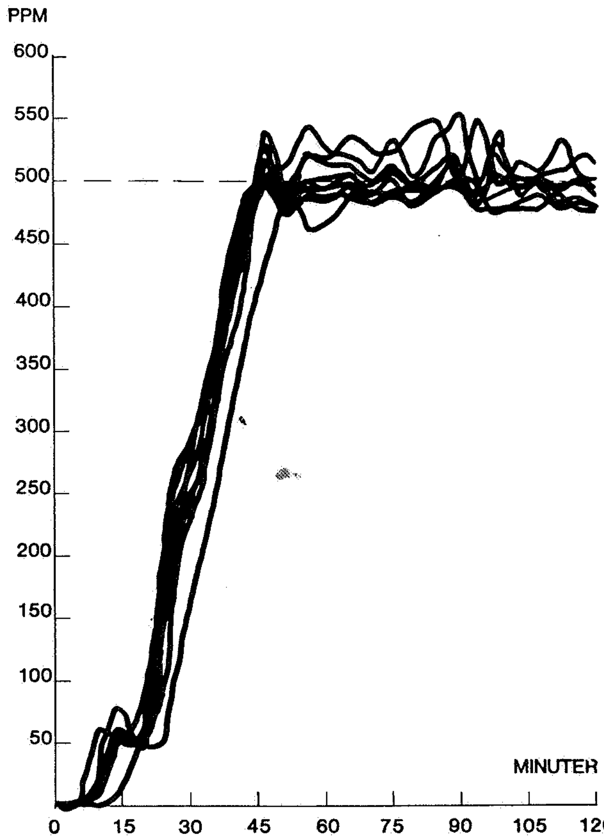


Figure 6. Concentrations of tracer gas as a function of time at nine different locations.

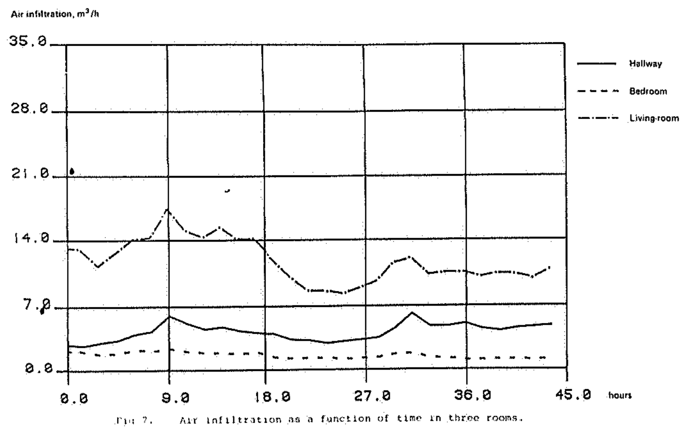


Figure 7. Air infiltration as a function of time in three rooms.

For 45 hours tracer gas was injected into each room and the concentration was maintained at a constant level. The ventilation rate changed quite a lot from room to room and with time. One bedroom had hardly any ventilation at all, while the living-room was well ventilated (see Figure 7).

Conclusions

An automated air infiltration measurement system has been developed with which continuous air infiltration measurements can be made. The supply of fresh air can be monitored simultaneously in nine different rooms. The ventilation rate is given directly in m^3/hr. There is no need for any complicated estimation of the effective volume. The system can also be used for constant tracer gas flow measurements and decay measurements.

Recent Acquisitions

The following papers have recently been acquired by the Air Infiltration Centre's library:

*1. Warren, P.R.
A simple method for predicting infiltration rates in housing.
Proceedings of CIB W67 3rd International Symposium 'Energy Conservation in the Built Environment', March 30 – April 1, 1982.

Proposes a simple equation, derived using a more complex theoretical model, for predicting the infiltration performance of houses.

2. Lofving, C., Nystrom, F.
The application of structural measures for energy conservation in existing buildings.
Swedish Council for Building Research Report D4:1982, 94pp.

Illustrates the measures which can be carried out on building elements in order to save energy.

*3. Warren, B.E.
Energy saving in buildings by control of ventilation as a function of indoor carbon dioxide concentration.
Building Services Engineering Research and Technology, 1982, Vol. 3, No. 1, p4–12.

*4. Alexander, D.K., Etheridge, D.W.
Natural and mechanical ventilation rates in a detached house: predictions.
Applied Science 1982, Vol. 10, No. 2, p79–95.

The results of a prediction method are compared with experimental measures.

5. Young, G.S., Hagopian, J.H., Hoyle, E.R.
Potential health effects of residential energy conservation methods.
NTIS Report PB82 133 315.

Reviews literature and presents annotated bibliographies for indoor air quality, pollution, health effects and air infiltration.

Copies of the papers marked with an asterisk are available from the AIC to organisations in participating countries. The remainder are available on loan.

Forthcoming Conferences

1. ASHRAE/DOE Conference
Thermal Performance of the Exterior Envelopes of Buildings II
Las Vegas, Nevada, USA
December 5–9 1982

Topics covered include:

- *measurement of energy use*
- *air infiltration*
- *standards for energy conservation*
- *retrofitting for energy conservation*
- *modelling building envelope systems*

Further details from:

Marjorie C. Matthews
Oak Ridge National Laboratory
PO Box X
Oak Ridge
TN 37830
USA

2. System Simulation in Buildings
University of Liège, Liège, Belgium
December 6–8 1982

Further information from:

Jean Lebrun
SSB/Dec 82
Laboratoire de Physique de Bâtiment
Avenue des Tilleuls 15 – Bât.D1
D-4000 Liège
Belgium

3. Second International Congress on Building Energy Management
Ames, Iowa, USA
May 31 – June 3 1983

Further information from:

Office of the Secretariat
c/o Prof. James E. Wood
Iowa State University
102 Scheman Building
Ames
Iowa 50011
USA

4. ASHRAE Semi-Annual Meeting
Washington, USA
June 26–30 1983

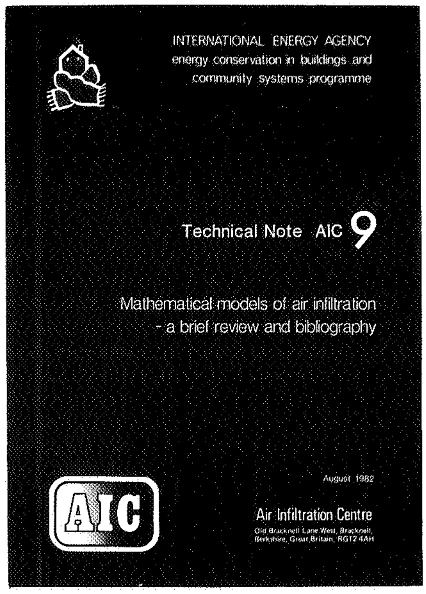
Will include a symposium entitled 'Air Infiltration Model Validation'

5. 9th CIB Congress
Stockholm, Sweden
August 15–19 1983

Further details from:

The National Swedish Institute for Building Research
PO Box 785
S-801 29 Gävle
Sweden

AIC Technical Note 9
Mathematical Models of Air Infiltration – A Brief Review and Bibliography



This technical note contains a brief analysis and bibliography of mathematical modelling techniques used in the estimation of air infiltration in buildings. The theory behind air infiltration modelling is described and general details of 14 models are given. These range in complexity from 'single cell' approaches, in which the interior of the building is assumed to be at a single uniform pressure, to 'multi-cell' methods, in which the interior is partitioned into areas of differing pressures interconnected by flow paths. The various applications of these models and details of the key parameters that must be defined in order to obtain reliable estimates of air infiltration are described. The bibliography contains abstracts of papers from *AIRBASE* referred to in the review.

Available free-of-charge to participating countries' only.

Publications Order Form

Name . . . .

Organisation . . . .

Address . . . .

. . . .

		Non-participating Countries £ sterling	Participating Countries £ sterling
Please forward the following publications:			
Technical Note AIC-TN-9-82	copies	Not available	Free
3rd Conference Proceedings.	copies	17.00	17.00
Supplement to 3rd Conference Proceedings	copies	6.50	6.50
Please add my name to your mailing lists as follows:			
Air Infiltration Review (quarterly)	copies	Free	Free
Recent Additions to *AIRBASE* (bi-monthly)	copies	Not available	Free

I enclose a cheque made payable to BSRIA (AIC) for:

£ . . . . drawn on a UK bank.

Signed. . . . . Dated. . . . .

Representatives and Nominated Organisations

Canada

*R. Dumont,
Division of Building Research,
National Research Council,
Saskatoon, Saskatchewan,
Canada S7N 0W9.
(Tel: 306.665.4200)

J. Shaw,
Division of Building Research,
National Research Council,
Ottawa, Canada,
K1A 0R6.
(Tel: 613.993.1421)
(Telex: 0533145)

J.H. White,
Research Division,
Canada Mortgage and
Housing Corporation,
Montreal Road, National Office,
Ottawa, Ontario, Canada, K1A 0P7.
(Tel: 613.748-2309)
(Telex: 053/3674)

Denmark

*P.F. Collet,
Technological Institute,
Byggeteknik,
Post Box 141, Gregersensvej,
DK 2630 Tastrup, Denmark,
(Tel: 02-996611)
(Telex: 33416)

Italy

*M. Cali,
Instituto di Fisica Tecnica,
Politecnico di Torino,
Corso Duca degli Abruzzi, 24,
10129 Torino, Italy.
(Tel: 011-537353)
(Telex: 220646)

Roberto Zecchin,
Istituto di Fisica Tecnica,
Universita degli Studi,
Via Marzolo, 9/11,
35100 Padova, Italy.

Walter Esposti,
ICITE, Viale Lombardia, 49,
Fraz, Sesto Ulteriano,
20098 S. Giuliano Milanese (M1),
Italy.

Netherlands

*W. de Gids,
Institute for Environmental
Hygiene—TNO,
P.O. Box 214,
Delft, Netherlands.
(Tel: 015-569330)
(Telex: 38071)

New Zealand

*H.A. Trethowen,
Building Research Association
of New Zealand Inc (BRANZ),
Private Bag,
Porirua,
New Zealand.
(Tel: Wellington (04) 357600)
(Telegrams: BRANZ Wellington)

Norway

*T.Ø. Ramstad,
Norwegian Building
Research Institute,
Box 322,
Blindern,
Oslo 3, Norway.
(Tel: 02-469880)

S. Uvsløkk,
Norwegian Building
Research Institute,
Högskoleringen 7,
7034 Trondheim—NTH,
Norway.
(Tel: 075-93 390)

Sweden

*L. Sundbom,
Swedish Council for
Building Research,
St. Göransgatan 66,
S-112 30 Stockholm,
Sweden.
(Tel: 08-540640)
(Telex: 10398)

A. Elmroth,
Royal Institute of Technology,
Division of Building Technology,
S-100 44 Stockholm,
Sweden.
(Tel: 08-787 70 00)
(Telex: 10389)

Switzerland

*P. Hartmann, EMPA,
Section 151, Ueberlandstrasse,
CH 8600 Duebendorf,
Switzerland.
(Tel: 01-8234251)
(Telex: 53817)

The Oscar Faber Partnership (UK)

*D. Curtis,
The Oscar Faber Partnership,
Marlborough House,
Upper Marlborough Road,
St. Albans, Herts, AL1 3UT,
Great Britain.
(Tel: 0727-59111)
(Telex: 889072)

G.J. Kennedy, ETSU, AERE,
Harwell, Oxon, OX11 0RA,
Great Britain.
(Tel: 0235-834621)
(Telex: 83135)

P. Robertson, BSRU,
University of Glasgow,
3 Lilybank Gardens,
Glasgow, G12 8RZ,
Great Britain.
(Tel: 041-334-2269)
(Telex: 778421)

BSRIA,
Old Bracknell Lane West,
Bracknell, Berks,
RG12 4AH, Great Britain.
(Tel: 0344-25071)
(Telex: 848288)

USA

*H. Ross,
Department of Energy,
Buildings Division,
Mail Stop GH-068,
1000 Independence Avenue S.W.,
Washington D.C. 20585, USA.
(Tel: 202/252-9191)
(Telex: 255 710 822 0176)

R. Grot, Building Thermal &
Service Systems Division,
Centre for Buidling Technology,
National Bureau of Standards,
Washington D.C. 20234, USA.
(Tel: 301/921-3470)

D.T. Grimsrud,
Energy & Environment Division,
Building 90, Room 3078,
Lawrence Berkeley Laboratory,
Berkeley, California 947[illegible]
USA.
(Tel: 415/486-4023)
(Telex: 255 910 366 2037)

D. Harrje, Centre for Energy &
Environmental Studies,
Princeton University,
Princeton, New Jersey 08544,
USA.
(Tel: 609-452-5190/5467)

*Steering Group Representative.

Published by

Air Infiltration Centre,
Old Bracknell Lane West,
Bracknell,
Berkshire, RG12 4AH,
Great Britain.

Tel: National 0344 53123
International +44 344 53123

Telex: 848288 (BSRIAC G)

Head of AIC: Peter J. Jackman,
BTech CEng MIMechE MCIBS

Operating Agent: The Oscar Faber Partnership

ISSN: 0143-6643