Air Infiltration Review

a quarterly newsletter from the IEA Air Infiltration and Ventilation Centre

International Energy Agency - AIVC

Vol. 16, No. 2, March 1995

Aerosols Indoors: Deposition on Indoor Surfaces

Goddard, A.J.H., Byrne*, M.A., Lange**, C. and J. Roed**.*

**Energy Systems Section, Mech. Eng. Dept., Imperial College, London, UK*

***Environmental Science & Technology Dept., Risoe National Laboratory, Roskilde, Denmark.*

1. Introduction

Current interest in fine particles in the urban environment, and their health effects, has strengthened interest in aerosols in the indoor environment; how do indoor air concentrations and settled dust levels depend upon the main variables - building types (including ventilation characteristics), occupancy conditions and contaminant aerosol size distributions? In this review we concentrate upon the details of the aerosol deposition process upon surfaces.

In assessing whether airborne particulate (aerosol) transport in buildings should be assessed by test measurements and/or by modelling, the criterion is building complexity. For more than, say, two interconnected rooms even the use of our very sensitive aerosol labelling methods, described elsewhere [1], would require aerosol concentrations near to the release point such as to lead to the agglomeration of particles - making the test non-representative. There are thus sound reasons for concentrating research on the deposition rates to particular indoor surfaces - the resulting data may then be used in CFD codes or in simple compartment models where appropriate. Settled dust levels may also be of interest to the building designer. The release of test aerosols into individual building spaces remains an option.

For low ventilation rate/well-mixed conditions, surface deposition significantly reduces the airborne concentration, while for high ventilation rates where the structure of the flow may be important, deposition rates will be less than air exchange rate and airborne concentrations will be determined by the air exchange. Under these latter conditions particles will effectively follow the flow (apart from

In this issue

very large particles), but again local surface and flow characteristics will determine settled dust rates.

The starting point for research into particle transport indoors has to be the single well-mixed room with relatively low exchange rates. When this is understood we can progress with confidence to model more complex building environments.

2. Simple models for indoor air concentrations

The deposition rate to a surface may be expressed in terms of the deposition velocity V_d where

$$V_d\ (ms^{-1}) = R\ (m^{-2}s^{-1})$$

$$C(m^{-3})$$

where C is the aerosol concentration outside the laminar sub layer near the particular surface and R is the flux of particles to the surface. When experimental measurements are available, V_d can be used in simple compartment models for indoor air concentration, or used as a local boundary condition for complex computational fluid dynamics (CFD) codes. It will depend on the local degree of turbulence, nature of the surface (roughness, thermal, electrostatic etc). In addition, large particles will settle due to gravity; this sedimentation process tends to enhance V_d on floors and to some degree on walls, relative to that for the ceiling.

To demonstrate the effectiveness of the deposition process in reducing indoor concentrations, consider a single room with the aerosol well-mixed. The accompanying figures show steady state indoor air concentrations, calculated using experimentally derived (by the authors) aerosol deposition rates, averaged over all surfaces of an unfurnished room, in a simple compartment model, relative to (a) outdoor aerosol concentrations (b) the source rate for an indoor source. These are plotted versus air exchange rate and aerosol mass median aerodynamic diameter (MMAD). Note that MMAD allows the behaviour of particles of particular characteristics to be corrected to those of spherical unit density particles. Particularly for low air exchange rates, the influence of deposition upon indoor air concentration is very significant - it can account for the indoor/outdoor concentration ratios measured under conditions of natural ventilation, by other authors, for ambient particles of outdoor origin .

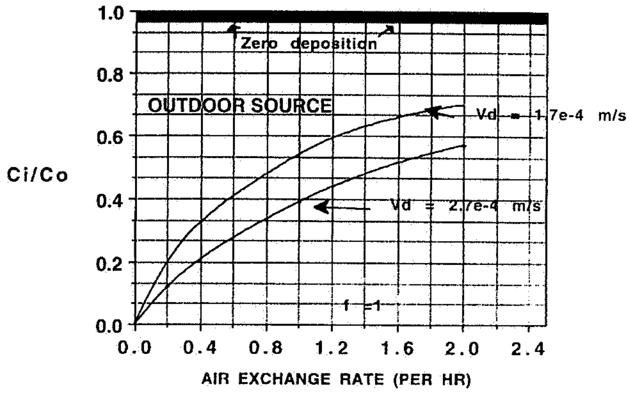


Figure 1. Calculated steady-state indoor/outdoor aerosol concentration ratio (Ci/Co), using experimentally-determined deposition velocity (Vd) data for 2.5 mm and 4.5 mm MMAD particles. The case for zero deposition is also shown. A filtration factor (f) of unity is assumed.

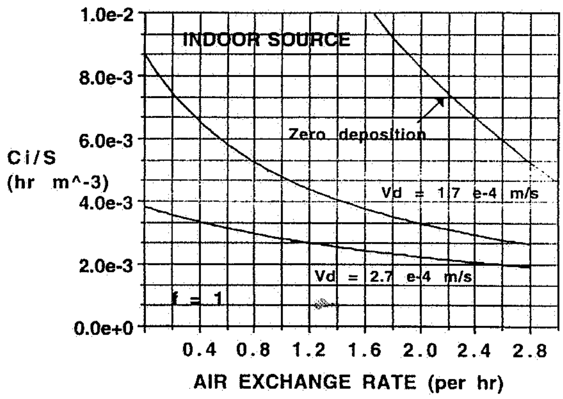


Figure 2. Calculated steady-state indoor aerosol concentration (Ci) relative to indoor source rate (S), using experimentally-determined deposition velocity (Vd) data for 2.5 mm and 4.5 mm MMAD particles. The case for zero deposition is also shown.

We should note that in the above simple model the building fabric has been assumed to have zero

Air Infiltration Review

Editor: Janet Blacknell

Air Infiltration Review has a quarterly circulation of 3,500 copies and is currently distributed to organisations in 40 countries. Short articles or correspondence of a general technical nature related to the subject of air infiltration and ventilation are welcome for possible inclusion in AIR. Articles intended for publication must be written in English and should not exceed 1,500 words in length. If you wish to contribute to AIR, please contact the Air Infiltration and Ventilation Centre. Please note that all submitted papers should use SI units.

filtration effect (i.e. the filtration factor has a value of unity); there is some experimental evidence [2] that this is the case for sub-micron particles entering naturally ventilated buildings, while data is lacking for larger particles.

3. Measured aerosol deposition rates indoors

We have noted the importance of indoor deposition, together with air exchange, in controlling indoor aerosol concentration. We outline below some steps in our research which aims to generate a comprehensive set of deposition velocities for indoor surfaces.

3.1. Average deposition velocities in unfurnished and furnished rooms

Using a sensitive particle labelling technique, average deposition velocities in a room have been measured using surrogate aerosols of a range of single sizes (in each test the aerosols were monodisperse). This technique may be used for both submicron and supra micron aerosols. It involves labelling aerosol, before it is dispersed, with a tracer element; samples taken in the room; air filters, surface samples, clothing samples etc may then be analysed by neutron activation analysis and an aerosol mass balance for the whole room checked if required. The method provides accurate non-destructive analysis of these samples. In addition, required aerosols levels are so low that there are no problems of aerosol agglomeration, the test aerosol is distinguished clearly from ambient aerosol, and the effects of occupancy may be studied with only modest breathing protection. Figure 3 shows the layout of the test room for a typical aerosol deposition velocity measurement.

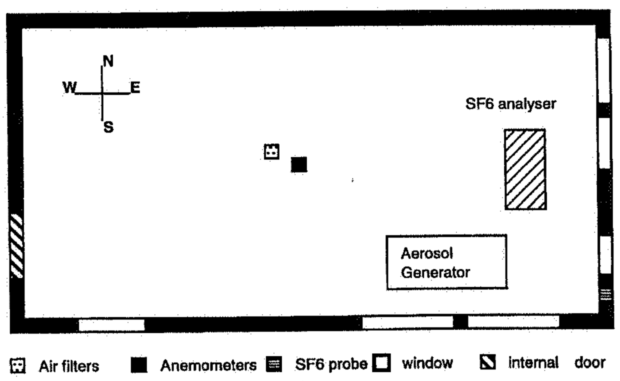


Figure 3. Typical test room configuration.

Figure 4 shows the rate of decrease of a test aerosol within one room in a UK test house, and the corresponding reduction in SF6 tracer gas concentration with time (which gives the air exchange rate). From the difference between the two rate constants that for deposition alone may be found. Trends in data [3] show that average deposition velocity to all the room surfaces, obtained by multiplying the aerosol deposition rate constant by the volume-to surface-area ratio of the room, increased with the presence of furniture and with the number of people in a room but that enhanced air circulation rates within the room have a relatively small effect on the deposition process.

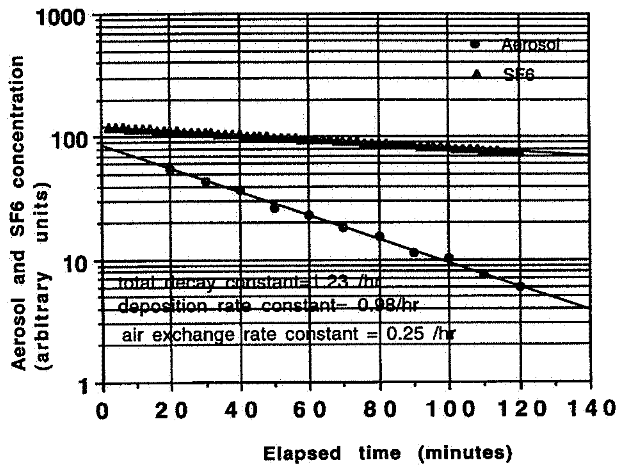


Figure 4. Aerosol and tracer gas concentration decay curves in a single room, from which decay rate constants can be calculated.

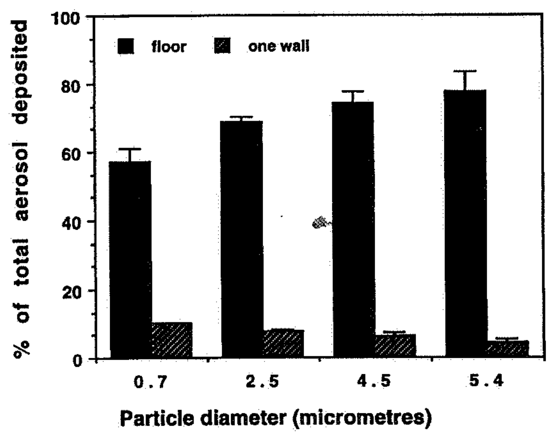


Figure 5. Measured relative aerosol particle mass fluxes to the floor and one wall of a test chamber.

3.2 Deposition to individual surfaces within a room

Experiments in an aerosol test chamber (simulating a small room) allow deposition to individual wall surfaces to be studied (comparable studies can be carried out in a real building environment). An initial test is that of mass balance - does the sum of deposition rates measured to individual surfaces match that derived from the loss rate as given by time decay (see the previous section). This has been confirmed within experimental errors. Figure 5 shows the proportion of aerosol deposition to the floor and one wall of an aluminium test chamber in the form of a 2m cube. The dominance of gravitational sedimentation for the large particles can be seen. However, for submicron particles the proportion deposited to walls and the floor is approximately equal. The total deposition in such a chamber, with circulation maintained by a small fan, is consistent with theoretical models.

3.3 Influence of vertical surface roughness on aerosol deposition

The availability of two independent methods (the time decay and monitoring individual surfaces) to determine the particle flux to test chamber walls, allows differential measurements to be undertaken. The change in the time decay rate resulting from changing the roughness of one wall enables the deposition velocity to that wall to be determined, and this in turn may be related to the friction velocity (a characteristic of the effect of a surface upon the local degree of air turbulence). Friction velocities were determined separately in a small wind tunnel.

Figure 6 shows the deposition velocity to vertical surfaces of varying degrees of roughness for a supra-micron aerosol. For the smoothest surface the deposition velocity is relatively low and then increases with increased surface roughness due to the enhancement of turbulence by the presence of the rough surface.

4. Conclusions

We have developed a new method of labelling particulate that may be used in low concentrations to investigate air concentrations and settled dust levels within test rooms in buildings - taking into account occupancy. Particulate levels in the air and settled on surfaces can be measured accurately and economically through neutron activation analysis to yield deposition velocities. While, for large particles, sedimentation to horizontal surfaces will dominate, for submicron particles deposition to walls and other vertical surfaces is significant. If the sole interest is in air concentrations, deposition is a very important factor in determining indoor air concentrations (whether the aerosol is of outdoor or indoor origin) for low air exchange rates. The data we are generating can provide boundary conditions both for simple and for CFD models so that levels of settled particulate can be estimated. This article, which has focussed on naturally ventilated buildings, has not covered the potentially important topics of thermal and electrostatic effects within rooms nor of deposition on people (these are the subject of current research), nor has it covered building fabric filtration or mechanical transport of particulate into buildings.

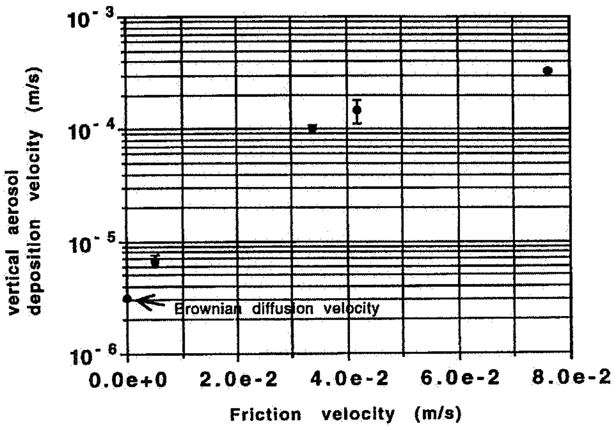


Figure 6. Measured aerosol deposition velocities, for a single aerosol particle size, to a vertical wall of a test chamber covered with materials of varying roughness (characterised by friction velocity).

References

1. **Byrne, M.A., Lange, C., Goddard, A.J.H. and J. Roed (1992).** Indoor aerosol deposition studies using neutron-activatable tracers. *J. Aerosol Sci.*, 23 S1, pp 543-546.

2. **Roed, J. and R.J. Cannell (1987).** Relationship between indoor and outdoor aerosol concentration following the Chernobyl accident. Radiation Protection Dosimetry, 21, pp 107-110.

3. **Lange, C., Roed, J., Byrne, M.A. and A.J.H. Goddard (1994).** Indoor aerosol deposition studies using rare-earth tagged particles. Proceedings of the 1994 European aerosol conference.

ASHRAE - the First 100 Years

A report on the ASHRAE Centennial Meeting, Chicago
28th January - 1st February 1995

by Martin W Liddament, Head, AIVC

The Beginning

The 100th year of ASHRAE was celebrated by looking both back to its formation and forward to its future. The plenary session re-enacted the formation of the Society, then called The American Society of Heating and Ventilating Engineers, and quoted from the inaugural speech at which the first President, Edward Bates, stated that " ... we should not cease our labors when public buildings are thoroughly warmed and ventilated, but our zeal for a good cause should eventually take us into every building which shall be constructed for any purpose. There are cases where factories and workshops are fairly well ventilated but these are rare. Every family has the right to have an abundance of fresh air, even if it is not aware of its rights."

Included among the Society's inaugural objectives were: - the promotion of arts and sciences connected with heating and ventilating. - improvements of the mechanical construction of the various apparatus used for heating and ventilating. - to establish a clearly defined minimum standard for heating and ventilating in all classes of buildings. - the reading, discussion and publication of professional papers and the interchange of knowledge and experience among its members.

These have continued as fundamental objectives of ASHRAE as was evident at the Chicago Winter Meeting. Specific topics and sessions presented at Chicago included:

Where is Ventilation Going?

A presentation by Carl Lawson of Comprehensive Monitoring charted the history of ventilation systems from the methods of ancient times, through to Leonardo de Vinci's water driven fan, then on to natural gravity systems and, finally, to modern fan technology. He stressed that the role of research was to improve ventilation and air cleaning. In looking at today's technology he referred to the development of much more advanced codes and standards, the need to focus on air quality rather than quantity, the control of fire and smoke spread and the special needs of isolation areas in hospitals and clean room environments.

100 Years of Comfort Research

In a seminar entitled "100 years of Comfort Research", Professor Ole Fanger of the Technical University of Denmark gave a brief over-view of the recent history of ventilation. He reflected that up until close to the turn of the Century it was thought that metabolic carbon dioxide was a poison and that ventilation was needed to avoid its toxic effects. Pettenko in 1858, however, showed that this was not the case but concluded that CO_2 concentration was a good indicator of human odour. From the beginning of the century to the mid 1930's it was thought that ventilation was needed to avoid the spread of contagion.In 1893, Billings, a medical doctor, recommended a ventilation rate of 30 l/s.p for good health and an absolute minimum rate of 15 l/s.p. This minimum value was adopted by ASHVE as a Model Law which was accepted by 22 US States. The Contagion Theory was eventually disproved when it was shown that illness was spread by local influences such as direct contact and sneezing. The pioneering work of Yaglou in 1936-37 set the modern principles behind ventilation to provide for comfort. His work was based on analysing relationships between ventilation rate and odour intensity. Yaglou introduced a scale of odour intensity, as perceived by visitors to a space which varied in increments from no odour to intense odour. Test chamber studies showed that a ventilation rate equivalent to 8 l/s.p was needed to avoid exceeding a moderate odour intensity. In schools, rates as high as 19 l/s.p were needed to avoid exceeding the same intensity of odour . Until the 1980's, the primary source of pollution was seen as the occupant. Only since then have emissions from building fabrics and furnishings been considered.

ASHRAE Standard 62: Minimum Ventilation Rates for Acceptable Indoor Air Quality

The Committee responsible for revising Standard 62 met over a three day period to review the latest draft. It is intended that the new Standard should go for public review during the course of this year. There is still much discussion about the ventilation needed to provide a healthy environment but general agreement has been attained on how ventilation should be specified. Two methods are proposed, the first of which is based on prescribing flow rates while the second is based on an IAQ or alternative ventilation rate (AVR) procedure. The proposed prescription is based on a no smoking environment in which there are no strong or unusual sources. Ventilation rates are derived from three basic components; these are the occupants themselves, the activity of the occupant (e.g. sedentary, using PC's etc.) and the emission rate from furnishings and fabrics. The first two sources are based on a per person ventilation rate, while the third is based on a unit floor area ventilation rate. The AVR method is intended for determining the ventilation rate needed for high standards of air quality. It is determined by calculating separately the ventilation needed for health and comfort and selecting the greater of the two values.

Outdoor Air Quality

The local contamination of outdoor air in the vicinity of air intakes can represent a major source of poor indoor air quality. In a seminar on the numerical modelling of contamination from stacks, Professor David Wilson of the University of Alberta, Canada presented a simple algorithm that may be used to estimate the potential maximum pollutant concentration of the air close to stacks. It is intended that this approach be incorporated into the 1997 ASHRAE Fundamentals. A project proposal, authored in part by the AIVC, on the research and development of Guidelines for the siting of air intakes was given maximum priority rating by the ASHRAE Research Committee. Additionally, a forum on the need for a standard on the siting of air intakes endorsed the need to develop guidelines.

Multi-Zone Modelling

A symposium devoted to multi-zone air flow modelling illustrated the extent to which these techniques are becoming integrated into design procedures. Presentations covered experimental vs calculated comparisons, the simulation of pollutant transport, radon propagation and the evaluation of ventilation strategies. This symposium covered both offices and dwellings with multi-zone methods being used to simulate complex structures.

Energy Impact

Professor Don Colliver from the University of Kentucky gave a presentation on the energy needed to condition incoming air to comfort levels. This was based on his work undertaken at the AIVC in which hourly weather data from many sites throughout the United States and Europe were analysed. One observation was the similarity throughout many climatic zones in the total annual amount of energy needed for conditioning. However in some areas this was needed entirely for space heating while in others it was needed for latent and thermal cooling. The energy benefits of varying set point conditions were also analysed for each climate and were shown to be significant at many locations.

Forums

Forums provide the opportunity for informal discussion on specific topics. Topical subjects included:

(i) Energy Recovery Ventilator Controls

Interest at this forum was evenly split between domestic, commercial and industrial applications of heat recovery systems. For dwellings the need to consider seasonal control was discussed with energy recovery being needed in the winter heating and summer cooling seasons. During the shoulder seasons the thought was expressed that needs should be met by window opening. Other aspects included providing continuous background ventilation combined with occupant controlled boost in kitchens and bathrooms. In the commercial environment, controls were seen as necessary to meet relevant ventilation standards, specific indoor air quality requirements and any further needs of occupants. A need to separate IAQ concerns from heat recovery issues was expressed possibly by using CO_2 demand control. A further issue was the restriction of mechanical ventilation to periods of occupancy only. Other issues discussed included the integration of ventilation and heating controls, operating heat recovery devices with variable air volume systems and the use of individual room heat recovery ventilator and heat recovery devices in conference and smoking rooms.

(ii) Proper and Improper Use of CO_2 Control Systems

This forum attracted one of the largest audiences of the ASHRAE meeting and attempted to address the role of CO_2 monitoring. Among the speakers there was general agreement that CO_2 could not always be used as a surrogate of indoor air quality since other pollutants, such as VOC's and moisture, could be more dominant. Nevertheless sensors could provide an indication of how well a building ventilation system was performing. It could identify, for example, occupied areas of a building where air distribution was bad. Another speaker indicated how a careful monitoring and control strategy based on CO_2 monitoring had reduced ventilation demand in a troublesome office building without causing any complaint. For correct operation, one practitioner emphasised the need to monitor the difference in CO_2 concentration between the incoming and outgoing air rather than the absolute concentration. This was because the outside concentration itself, especially in urban locations, could vary considerably. One problem outlined concerning the use of CO_2 demand controlled strategies was that the rise in CO_2 concentration lagged behind occupant contamination, therefore there was a risk in delaying the provision of ventilation.

(iii) Should Standard 62 Require Mechanical Ventilation in Dwellings

Representatives from several countries outlined national philosophies towards domestic ventilation ranging from predominantly mechanical approaches in sealed buildings to reliance on window opening and air infiltration. Some speakers expressed the benefits of controlled ventilation while others thought that air sealing had gone too far and would not be acceptable in some countries. There was support, however, on a more voluntary approach in which guidelines on energy efficient purpose provided natural or mechanical ventilation rather than codes should be produced.

Further Information

Many other ventilation related topics were discussed in the various sessions and meetings. For further information contact Martin Liddament at the AIVC.

More details about the formation, history and objectives of ASHRAE are published in the ASHRAE Centennial retrospective entitled "Proclaiming the Truth". This publication is available direct from ASHRAE, price $49.00 US.

ASHRAE Fellowships for AIVC Colleagues

Awards were presented at the ASHRAE Centennial conference to Dr Max Sherman, AIVC US Steering Group representative, and Dr Don Colliver, a recent guest researcher at the Centre, who became fellows of ASHRAE. We extend our congratulations to them.

Survey of Mechanical Ventilation Systems in 30 Low Energy Dwellings in Germany

J Werner, U Rochard and J Zeller

Ingenieurbuero eboek, Tuebingen, Germany

1. Synopsis

This paper shows preliminary results of 18 out of 30 inspected ventilation systems in low rise, low energy residential buildings. We propose a method for the assessment of energy efficiency of ventilation systems.

The majority of the inspected exhaust systems fulfills the conditions for the demanded air flow rates and energy efficient operation. However, typically the distribution of airflows to the rooms of the supply zone is rather weather dependent due to insufficient airtightness of the building and large stack heights.

Two of five exhaust supply systems with heat recovery mismatch energy efficient operation due to high pressure drops. The airtightness of the buildings is insufficient.

Generally, there is a lack of operation and maintenance instructions. By optimized ductwork, fans, motors, and controller the electricity consumption could be reduced by more than 50%.

(This paper was first presented at the 15th AIVC Conference in 1994.)

2. Introduction

In Hesse, a state of the Federal Republic of Germany since 1987, an increasing number of low energy houses were constructed. This development was mainly due to political measures and sponsoring by the Hessian government as well as the work of the Institut Wohnen und Umwelt (IWU). One prerequisite for support from the sponsoring program was a mechanical ventilation system, which was demanded mainly by air quality reasons.

In 1993, a program was set up to investigate the performance of the supported ventilation systems. This work was done by the consulting office eboek under contract of the IWU, financed by the "Hessisches Ministerium fuer Umwelt, Energie und Bundesangelegenheiten". This paper covers preliminary results of 18 of the 30 tested ventilation systems. A final report will be available at the end of 1994.

3. Research Planning

3.1 Types of buildings and systems

All systems were installed in 2 to 3 storey 1 or 2 family houses or terraced houses.

The following system types are included in the study.

- Exhaust air with manual fan speed control (6 systems) (E_S)
- Exhaust air with humidity control (7 systems) (E_H)
- Exhaust and supply air system with heat recovery by heat exchanger (5 systems) (ESX)

3.2Measurement techniques

Since the ductwork contained no designed measurement planes, measurement of air flow rates, pressure drops etc. were often difficult to perform. Therefore a number of different measurement devices and techniques in accordance with /VDI 2079/ and VDI /2080/ were used. Measuring equipment and typical resulting errors are as follows:

- Power demand by digital wattmeter (typical error 5% of reading).
- Pressure levels by Pitot tube and digital micromanometer (typical error 6%, up to 20% o.r. at very low pressure differences).
- Air flow rate calculated by air velocity measurement by heated wire anemometer (typical error about 14% to 22% o.r.).
- Air flow rate by dynamic air speed indicator (System Halton) (typical error 7% to 12%).
- Air flow rates at air terminals by anemometer-hood (typical error 15% o.r.).
- Relative air flow distribution at terminals by pressure drop factors (typical errors 20% o.r.).

3.3Design conditions and assessment standards

The design conditions were designed as follows:

- 30 m^3/h outside air flow rate per person, at least 0.3 ac/h, and no more than 0.8 ac/h.
- All rooms with increased humidity or odour emissions are to be equipped with exhaust vents. According to /DIN 1946/ part 6 (draft) minimum air flow rates are established: kitchen 60 m^3/h, bathroom 40 m^3/h, toilet 20 m^3/h, at minimum air exchange rate of 2 ac/h. Minimum air flow rate for integrated cooker hoods 120 m^3/h.
- Living rooms with supply vents (ESX) or outside air supply vents (E) and openable windows.
- Openings in interior walls or doors to allow air flow from supply rooms to exhaust rooms.
- Demand controllable total air flow rates, at least 2 levels, 100% and 50%, of the design condition. An adjustable distribution of supplied air is desirable.
- No disturbing noise levels or draughts produced by the ventilation system.
- Good conditions for inspection and maintenance.
- Energy efficient operation of the ventilation system.

It is assumed that all living rooms and the kitchen have openable windows to allow additional natural ventilation on demand and during summertime. No severe indoor production rates of contaminants, for example radon or formaldehyde, should be present.

3.3.1 Energy efficiency

Today German building code /WSVO 1993/ is revised for environmental reasons. There is a statement for ventilation systems with recovery by air-to-air heat exchanger that the ratio of recovered useful heat to electricity consumption (COP) should exceed a factor 5. This is motivated by different emission levels into the atmosphere by generation of heating energy and electricity.

Using the heating degree day method /HMWT 1990/ specific ventilation energy losses Q_{ex} by 1 m^3/h air flow rate are calculated under typical German weather conditions for low energy houses over one heating period (degree day limits 20 Deg/12 Deg C, heating degree days dd = 3400 Kd, specific heat capacity of air $c_{p,air}$ = 0.34 Wh/(m^3K)). They amount to

$Q_{ex} = c_{p,air} * dd * 24 = 0.34 * 3400 * 24 = 27744$ [Wh^2/m^3]) [1]

In order to reach the COP of 5, the maximum allowable air-flow-specific electric power consumption is calculated by

$P_{spez,max,ESX} = Q_{ex} * eta_x / (t_{op} * COP)$

Assuming a mean recovery effectiveness eta_x of 70% and an operation period from 1 Sep to 31 May (operating time t_{op} = 6552 h/year), yields the limiting value of air-flow-specific power

$P_{spez,max,ESX}$ = 0,61 Wh/m^3

This number is used as a threshold condition for the energy efficiency of ESX systems.

Assuming an exhaust only system to be one half of an ESX-system the limit for energy efficient exhaust systems amounts to

$P_{spez,max,E} = P_{smez,\ max,ESX} * 0.5 = 0.3$ Wh/m^3

4. Results

4.1 System design

system name and type	ventil. volume (m³)	liv. area (m²)	actual occup. (person)	design air flow rate (m³/h)	area spec. rate (m³/(hm²))	air exch. rate (ac/h)
FR, E_S	422	179	5	180	1,01	0,43
BU, E_S	300	131	4	160	1,22	0,53
BE, E_S	477	205	3	150	0,73	0,29
HA, E_S	366	140	4	140	1,00	0,38
WH, E_S	513	201	4	180	0,90	0,35
MU, E_S	341	131	5	180	1,37	0,53
WU, E_H	501	188	5	180	0,96	0,36
LA, E_H	476	181	2	180	0,99	0,38
HG, E_H	515	194	3	180	0,93	0,35
HL, E_H	347	118	2	100	0,85	0,29
GS, E_H	359	144	4	140	0,97	0,39
FL, E_H	327	116	3	120	1,03	0,37
KU, E_H	768	307	7	300	0,98	0,39
PR, ESX	427	178	4	180	1,01	0,42
OT, ESX	450	201	5	180	0,90	0,40
RK, ESX	910	441	6	300	0,68	0,33
SC, ESX	389	168	4	160	0,95	0,41
WL, ESX	465	150	3	180	1,20	0,39
[illegible]	[illegible]	[illegible]	4	177	[illegible]	[illegible]

Table 1: Basic data of buildings and design values of ventilation systems (E_S: exhaust system fan speed controlled, E_H: exhaust system humidity controlled, ESX exhaust supply system with air to air heat exchanger

Table 1 shows the basic data of the systems and building. The system name is an internal code.

In most buildings, assignment of rooms to supply or exhaust zones was correct.

4.2 Air flow and air exchange rates

Of the inspected 18 systems 14 almost met the design values. Three systems had air flow rates which were too low. The reason was mainly due to high pressure drops caused by poor design or installation of ductwork. In one exhaust system the distribution of exhaust air to the rooms was totally wrong, because some vents were taped or not installed.

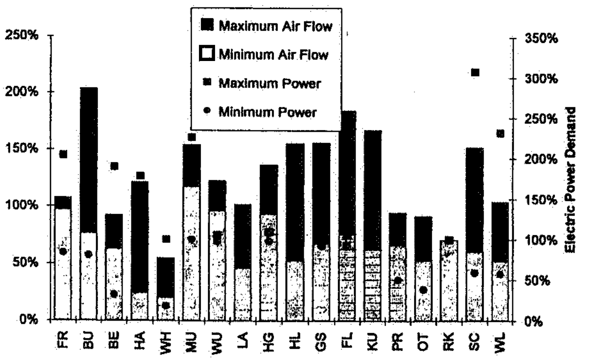


Figure 1: Control range of air flow rates and electric power demand applied to values at design condition level.

Moreover, most systems exhibited more or less severe weaknesses:

- In 9 out of 13 buildings with exhaust systems airtightness was insufficient or the stack height too large, so the ventilation rate and especially the ventilation of rooms with outside air supply vents was strongly influenced by stack and wind generated forces. Visible indicator for stack driven exfiltration in some buildings was the dust deposition on the filters of the outside air supply vents: at the ground floor the filter was dirty on the outside, at the middle floor dirt settled on both sides, at the upper floor mainly the inside of the filter was dirty. In some rooms of these houses regular additional ventilation by windows will be necessary.
- The airtightness in all buildings with ESX systems was insufficient compared to recommendations /SIA 180/. This will result in considerable additional in- and exfiltration. The ventilation losses of the buildings, will be considerably higher than predicted by calculations, assuming an airtight envelope /Werner 1993/.
- Air flow rate of integrated cooker hoods were not sufficient for a high capture capacity.

For some systems sound pressure levels were too high in the design level position; in some cases this was caused by missing sound attenuators, in some cases by sound generation in ductwork.

- In some systems draughts were found due to wrong placement or wrong type of supply vents.

For about 50% of the systems the range of air flow rate control was not sufficient. For speed controlled systems this was due to wrong balancing between the characteristics of ductwork and fan or oversized fans. For the humidity controlled systems this was due to high pressure losses in the ductwork compared to the pressure drop of the humidity controlled air outlet. One of the systems had only an ON-OFF switch. Figure 1 shows the relative variation of air flow rate by control and the electric power demand applied to design condition levels.

4.3 Maintenance and inspection

Almost no operating and maintenance instructions for the ventilation systems were available; in some cases there were data sheets by component manufacturers.

Accessibility of fans and filters for inspection and maintenance purposes was often poor. In many cases this was obviously due to total lack of planning:

- Turning some fan housings by 180 Deg would improve the accessibility of the maintenance flap and also reduce bends in the ductwork
- Removal of one filter is impossible because of a later installation of thermal insulation of a hot water storage tank.

In many cases dirt was found in fans and ductwork dating from the construction period 2 or 3 years ago. Besides dust, also pieces of polystyrene insulation were found, which was a reason for low air flow rates and noise nuisance.

Frequently fans, filters, or vents were not clean, especially in the systems with integrated cooker hood. Figure 2 shows the characteristics of pressure and electric power of a fan prior to and after cleaning /Rochard 1994/. Improper maintenance is the most prominent reason for reduced air flow rates and air quality problems.

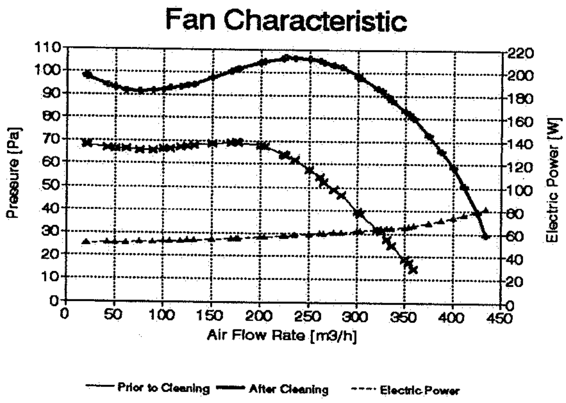


Figure 2: Characteristic of a fan prior to and after cleaning.

None of the systems had inspection protocols or tables with adjustment dimensions for vents or other adjustable parts.

Since the occupants of the inspected single family and terraced houses are not experts in ventilation systems, detailed and comprehensible maintenance, instruction, and operation documents are indispensable.

4.4 Ductwork

In all systems ductwork consisted of circular tubes, normally made by metal sheet coated with zinc or corrugated flexible metal tubes, in one case plastic tubes of plumbing system type were used.

Typical pressure drops of the inspected exhaust systems amounted to 75 to 100 Pa, for ESX systems a range from 100 to 300 Pa was found (cumulated of exhaust and supply ducts). Recalculations of the pressure drops of the ductwork typically showed possible improvements: avoidable bendings, too narrow diameters, sharply bent or squashed flexible tubes, wrong air outlets and so on.

Improper fixing or jointing of ducts was frequently found, some ducts were found to be completely disjointed (tape got loose and the wrongly fixed tubes slipped away).

4.5 Efficiency

Measurement of the total air flow, the total static pressure in front of, and after the fan, and the energy consumption of the motor were used to calculate the systems' overall efficiency (Figure 3). The efficiency increased with the size of air flow. Except one, all fans were of radial type with forward leaning fan blades.

The low efficiency of the systems was due to blade and motor type used in small fans, electronic motor controllers, the position of fan blades in the casing, dirty blades, and working conditions outside the range of optimum fan efficiency.

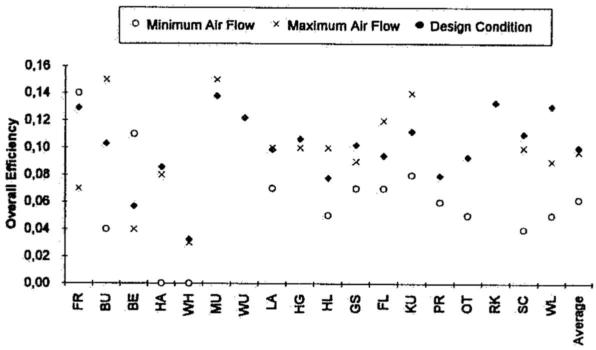


Figure 3: Measured overall efficiency of ventilation systems

4.6 Electrical energy consumption

4.6.1 Exhaust systems

The mean electric power of the fans at design conditions ranged from 31 to 76 W, the average air flow specific power amounted to 0,27 Wh/m^3, values spread between 0,17 and 0,57 Wh/m^3, out of 13 exhaust systems exceeded the limit of 0,3 Wh/m^3. Improving the ductwork will lower electricity consumption in speed controlled systems. In some humidity controlled systems the fan capacity was too high for the designed air flow rate.

Under design conditions the electricity consumption was calculated for 6000 operating hours using the measured power demand (Table 2).

Table 2: mean, minimum, and maximum values of calculated annual energy consumption per m^2 of living area of exhaust systems.

mean [kWh/(m^{2}a)]	minimum [kWh/(m^{2}a)]	maximum [kWh/(m^{2}a)]
1.49	1.21	1.97

4.6.2 Supply exhaust systems with heat recovery

The mean electric power accumulated of both fans at design conditions ranged from 39 to 151 W, the average air flow specific power amounted to 0.54 Wh/m³, values spread between 0.22 and 0.91 Wh/m³. Two systems have a very low value 0.3 Wh/m³, they were found to possess a very good hydraulic construction of the casing of heat exchanger and fans. Two systems show high values 0.8 Wh/m³, they exhibited relatively high pressure drops inside the casing due to hydraulic construction and additional heat exchangers for electric heat pumps.

Under design conditions the electricity consumption was calculated for 6000 operating hours using the measured power demand (Table 3)

Table 3: Mean, minimum, and maximum values of calculated annual energy consumption per m² of living area of exhaust supply systems.

mean [kWh/(m²)]	minimum [kWh/(m²a)]	maximum [kWh/(m²a)]
2.79	1.32	4.85

5. Measures for better efficiency

Possible measures for better efficiency of the systems are:

- Correct design of ductwork
- Correct choice of fans for operation in the optimum range of fan efficiency
- Correct adjustment of ductwork

The average specific consumption of the tested exhaust systems could be improved by the above listed measures to 40%. For ESX systems the possible reduction would lower the specific consumption by about 50%.

Taking into account newly developed technologies now available also for small ventilation systems (more efficient AC motors, improved speed controllers or DC motors), the specific energy consumption could be lowered from the present mean level by about 3/4 for exhaust systems and about 2/3 for ESX systems. More details are given in /Rochard 1994/. Two prototype systems currently under investigation show promising preliminary results.

6. Conclusions

- In general, the tested ventilation systems fulfill the requirement of energy efficiency. Nevertheless there is still a significant potential for improvement.
- Airtightness of buildings is insufficient. This leads to increased ventilation losses in buildings with ESX systems and to weather dependent ventilation of the supply zone in buildings with exhaust systems.
- Most ductwork and fans are far from the optimum performance. This corresponds to the result of almost total lack of design documents.
- Maintenance of the systems is unsatisfactory. This corresponds to complete lack of maintenance instructions and the poor accessibility to filters and fans, found frequently.
- To improve system performance in the future, better knowledge of architects, engineers and craftsmen is needed.
- Developed and available technologies with higher efficiencies should also be applied to ventilation systems in small buildings.

References

/DIN 1946/ DIN 1946 Teil 6 (Entwurf)
"Raumlufttechnik, Lueftung von Wohnungen, Anforderungen, Ausfuehrung, Pruefung", Beuth Verlag Berlin 8/91

/HMWT 1990/
"Energie im Hochbau, energiebewusste Gebaeudeplanung"
Hessisches Ministerium fuer Wirtschaft und Technik (editor) Wiesbaden 1990

/Rochard 1994/ Rochard U
"Rationeller Stromeinsatz bei Wohnungslueftungs-anlagen"
Diplomarbeit an der Fachhochschule fuer Technik, Esslingen 1994

/SIA 180/
"SIA 180: Waermeschutz im Hochbau"
Schweizerischer Ingenieur- und Architektenverein, Zuerich

/VDI 2079/ VDI 2079
"Abnahmepruefungen an Raumlufttechnischen Anlagen"
Duesseldorf, VDI-Gesellschaft fuer Technische Gebaeudeausruestung 3/83

/VDI 2080/ VDI 2080
"Messverfahren und Massgeraete fuer Raumlufttechnische Anlagen"
Duesseldorf, VDI-Gesellschaft fuer Technische Gebaeudeausruestung 10/84

/WSVO 1993/
"Verordnung ueber einen energiesparenden Waermeschutz bei Gebaeuden"
Bundesanzeiger Verlagsgesellschaft, Bonn 1993

/Werner 1993/ Werner J, Zeller J
"Die Luftdichtigkeit von Gebaeuden und ihre Bedeutung fuer die Funktion und Effizienz von Wohnungslueftungsanlagen"
in VDI-Bericht Nr. 1029, p 555 ff, Duesseldorf 1993

The AIVC's New Survey of Current Research into Air Infiltration, Ventilation and Indoor Air Quality

Survey conducted by Mark J Limb, Scientist, AIVC

An important objective of the Air Infiltration and Ventilation Centre is to disseminate information related to infiltration, ventilation, indoor air quality and energy use within buildings. The Survey of Current Research provides a platform for such an activity by supplying organisations in participating countries with regularly updated information about ongoing research in these fields. In particular, the major objectives of this survey are to encourage the international cross fertilization of research ideas and to promote co-operation between research organisations in different countries. Continuing interest in this research area has meant that, since 1980 when the first survey was conducted, there has been an increase in reported research projects of nearly 400% In this, the latest survey, a total of 256 replies have been received from seventeen different countries. All of the AIVC participating countries are represented in the survey. The origin and distribution of these are outlined in Figure 1.

The time being expended on individual projects was stated on 61% of survey replies, 70% of those replies where the amount of research time was stated,falls between 1000 and 6000 person hours (which equates to approximately 6 man-months to 3 man-years worth of research effort). Thirty six projects have longer staff allocation times, with 3 long term projects having over 40,000 person hours of staff time each. This is equivalent to 22 person years worth of research effort. These projects are often general ventilation/Indoor air quality programmes spanning several years of research effort. The overall picture is that there are an estimated one million hours of research effort in the field of ventilation, infiltration, indoor air quality and energy within buildings being documented by this survey.

In terms of total number of replies received and subjects covered, this survey represents the most comprehensive review of current research yet published by the AIVC. The project summaries from 17 countries cover all aspects of air leakage, ventilation and related indoor air quality research.

An interesting development is that research focusing on indoor air quality and the energy impact of ventilation have increased since the last survey. However, replies relating to tracer gas and air flow modelling studies are less than in previous surveys. Research in occupied buildings remains popular, while greater interest is being shown towards simulated occupancy and unoccupied studies. research in dwellings, commercial/office and Industrial buildings has remained stable since the last survey, however, the use of test chambers has notably risen by 32%. There has also been an

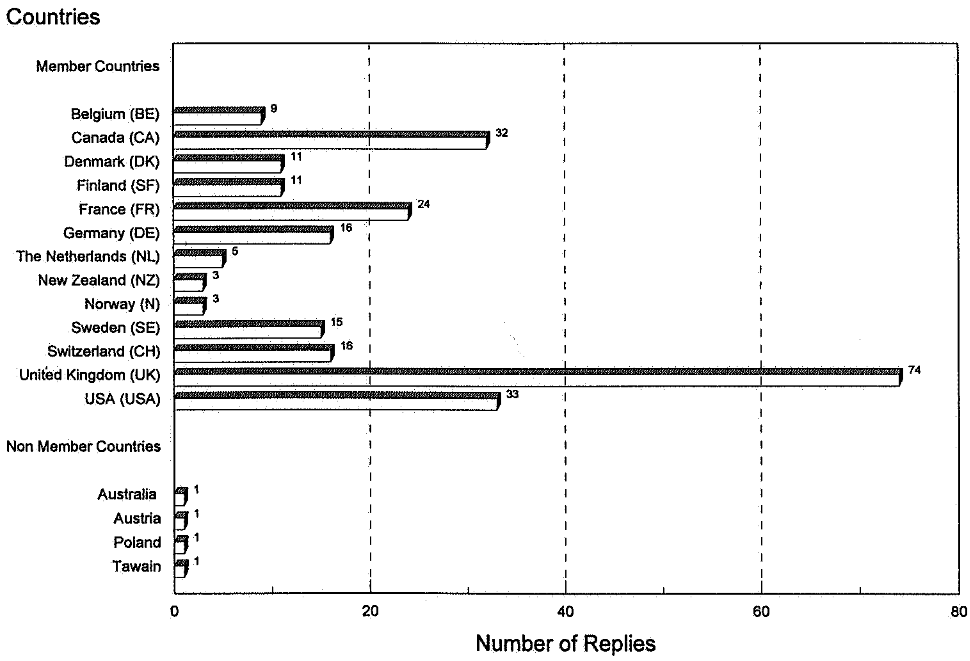


Figure 1: Distribution and origin of survey replies

increase in studies focusing on HVAC systems and their associated components.

The survey has been organised under several headings, information was collected about the specific objectives, project details, building and component type and information relating to the duration of each project. Tables were collated outlining the various subjects under investigation, from which the pie charts shown in Figures 2 to 5 were constructed.

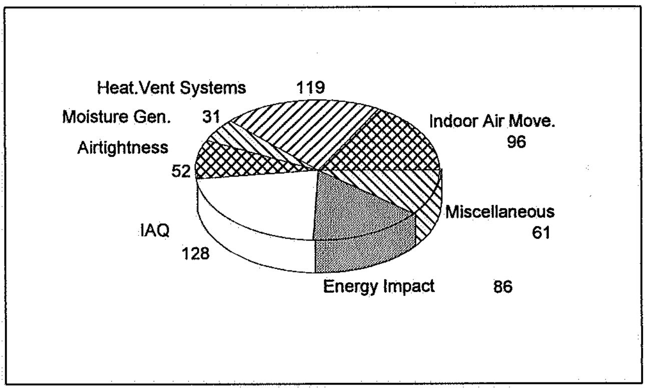


Figure 2 Classification of Specific Objectives

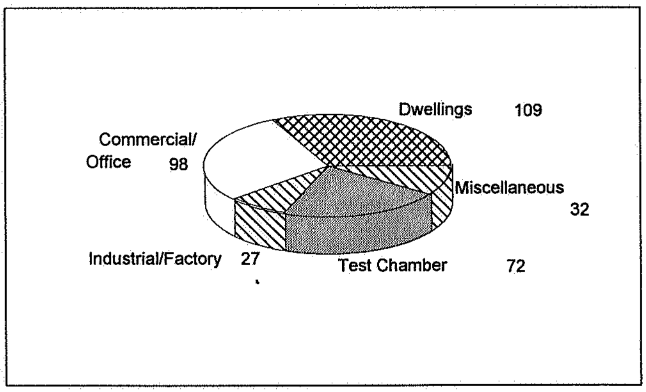


Figure 3 Classification of Building Types

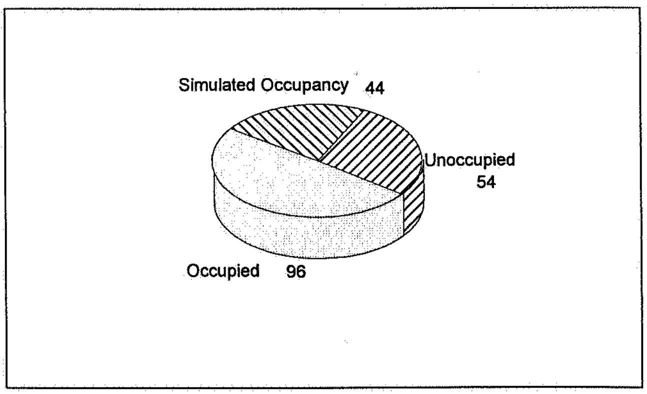


Figure 4 Classification of Building Occupancy

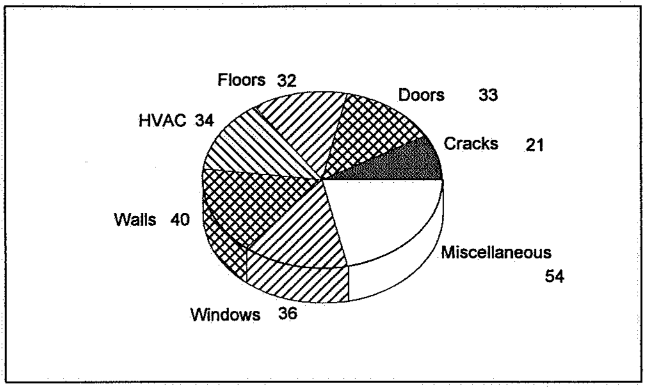


Figure 5 Classification of Component Type

The most popular specific objectives, outlined in figure 2 are those relating to indoor air quality with 128 replies and heating and ventilation systems with 119 replies. Indoor air movement and energy impact studies can be identified next, with 96 and 86 replies respectively. The final two main categories are airtightness/air leakage, with 52 replies and moisture generation with 31 replies. The remaining 61 replies can be classified as miscellaneous, of which there are 13 different sub divisions. These include thermal comfort, soil gas studies, model development, computational fluid dynamics (CFD) evaluation and research into passive cooling. Under the miscellaneous category the largest number of replies (13) related to soil gas studies. The other main area of interest was thermal comfort with 10 replies.

A more thorough discussion of the study is provided in the project details section and have been summarised in terms of measurement analysis and theoretical studies. Measurement studies cover 21 broad categories. The largest being energy consumption/heat loss/airtightness which accounts for 54 replies. Tracer gas studies attracted 38 replies with a further 5 studies using PFT techniques. Indoor air quality studies realised 37 replies, 20 projects focused on thermal comfort, 6 on moisture and 2 simply on general comfort. Measurement analysis on ventilation systems reported 5 studies. A more detailed analysis of the indoor climate based on the above replies revealed thermal comfort/draughts representing the largest division, accounting for 31 replies. IAQ/occupant sensitivity/perceived IAQ represents the second popular area of research with 29 replies.

Theoretical and numerical studies covered 17 broad categories; relating to either modelling /simulation, survey/databases or ventilation and heating systems.

Modelling/simulation studies included air quality/pollution and thermal comfort models with 40 replies. Thermal modelling has 36 replies and airflow modelling (general/multi zone and single zone) has a combined total of 53 replies. Surveys/database related projects include a total of 47 replies. Studies contributing to the development of standards and guidelines account for 38 replies, 10 replies are using or developing databases or expert systems. The final category (ventilation/heating systems) has 210 replies and covers eleven ventilation and heating system combinations. Mechanical ventilation and HVAC systems in general account for 79 replies. Other specific mechanical ventilation systems included demand controlled ventilation with 7 replies and displacement systems with 12 replies. Research into natural ventilation systems were identified by 28 replies.

Relevant variables related to either air change or indoor air quality are outlined in the parameters section of the analysis and include for example, weather variables, the performance of building components, the behaviour of occupants or sources of pollution. Two tables have been collated, the first outlines those parameters related to indoor air quality while the second concentrates on those related to air change. Parameters relating to IAQ can be divided into three main categories; weather and climate variables, physical parameters and pollutants. While those relating to air change can also be divided into three sections; weather and climate, physical parameters and building characteristics and performance.

Figure 3 outlines the different types of building used in the studies outlined by this survey. Dwellings can be seen to represent the greatest area of interest with 109 replies. The commercial/office sector also attracted a good deal of interest with 98 replies. Test chamber studies attracted 72 replies and the industrial/factory sector 27 replies. Miscellaneous buildings included atria, hospitals and school/lecture theatres. From Figure 4 it can be seen that over 50% of the building related studies are being undertaken in occupied premises. Simulated occupancy accounts for 23% while studies in unoccupied buildings account for 26%.

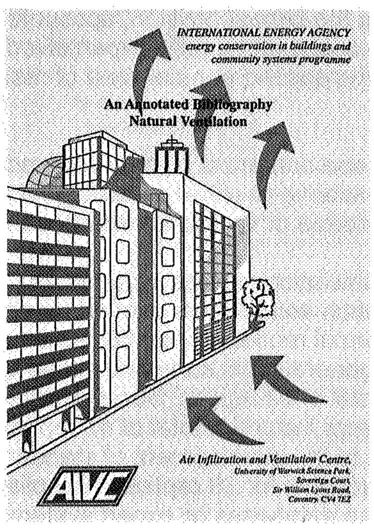
Building components under investigation are summarised in Figure 5. Six main components have been identified including walls (40 replies), windows (36 replies), doors (33 replies), floors (32 replies) and cracks (21 replies). HVAC systems also represent an important area of study with 34 replies. The miscellaneous category including 54 replies, is by far the biggest division, and consists of 17 different sub-divisions, including HVAC components, building materials, passive stack ventilation, and carpets.

The full replies to this survey, including researchers' names and contact numbers, are contained within the new Survey of Current Research Database which appears alongside the AIVC's Bibliographic Database "AIRBASE". The Survey first appeared in database format, alongside AIRBASE in 1990 and has since proved very popular. Full details of how to receive this database can be obtained directly from the AIVC. A full breakdown of the tables used to compile this analysis are contained within the new AIVC Technical Note 46 which is available free to participating countries, directly from the AIVC.

Other new publications from the AIVC

Annotated Bibliography - Natural Ventilation, by Mark J Limb

This report is a bibliographic review of technical papers, contained within the AIVC's bibliographic database, AIRBASE, dealing with natural ventilation in buildings. It is aimed at researchers, designers and engineers who would benefit from a bibliographic overview of research into this area.



Technical Note 45 Air-to-Air Heat Recovery in Ventilation, by Steve Irving

This Technical Note discusses the issues which influence the performance of heat recovery devices within typical building applications. The report is intended to cover the three main types of devices installed in ventilation systems in residential and commercial buildings.

- run around coils
- plate heat exchangers
- thermal wheels (rotary regenerators)

Other systems such as heat pipes are described briefly.

Chapter headings include:

- description of devices;
- factors influencing the selection of heat recovery devices;
- general factors influencing the operation of heat recovery devices;
- influence of building related issues.

This publication is available free of charge to enquirers from participating countries (See back page).

International Energy Agency

Air Infiltration and Ventilation Centre

16th Annual Conference

Implementing the Results of Ventilation Research

Palm Springs, California, USA

Tuesday 19th - Friday 22nd September 1995

Preliminary Announcement

Considerable effort has been devoted to research into ventilation technology and its impact on indoor air quality and energy demand. The purpose of the AIVC's 16th annual conference is to review the implementation of the results of recent research. Abstracts of papers on the following topics are particularly invited.

- ***Energy efficient ventilation strategies***

Ventilation methods have changed over the last 15 years from reliance on air infiltration and window opening to controlled mechanical and natural techniques. The requirements covering ventilation of dwellings and commercial buildings have also developed substantially in almost all IEA countries. Modern systems can be much more responsive to occupant needs, resulting in improved indoor air quality and substantial gains in energy efficiency. Intended papers should cover the application of new techniques and the results of field studies.

- ***Ventilation heat recovery***

Heat recovery systems may be used to advantage with almost all ventilation systems. Developments have progressed from air to air systems to heat pumps and controlled air flow through 'dynamic' insulation. Examples illustrating the performance and application of heat recovery systems are invited.

- ***Maintenance and long - term performance***

Reliability and ease of maintenance are key factors in ensuring the take up of complex systems. Papers are needed that cover these aspects in relation to problems, the development of codes of practice and designing for minimum maintenance.

- ***Controls and user interaction***

The interface between the system and the occupant has a significant impact on ventilation performance. Examples should cover user friendly controls and the needs of occupants.

- ***The application of mathematical models in design***

Modelling techniques have also developed considerably, with current models varying from simple evaluation tools to total building energy and air quality evaluation methods. Papers describing the demonstration and use of all types of models are welcome.

- ***Measurements for design and diagnostic analysis***

Measurement systems designed for research have given way to more user friendly products that can be applied by the less well skilled. It is proposed to cover examples illustrating the development and application of modern measurement methods.

Enquiries should be sent to Rhona Vickers at the Air Infiltration and Ventilation Centre, (details on back page).

Forthcoming Conferences

The Third International Conference on Carbon Dioxide Utilisation (ICCDU)
30 April - 4 May 1995
The University of Oklahoma, Oklahoma Center for Continuing Education, Norman, Oklahoma, USA
Contact: The Secretariat, ICCDU Conference, c/o Department of Chemistry & Biochemistry, The University of Oklahoma, Norman, OK 73019, USA
Tel: +1 405 325 3696, Fax: +1 405 325 6111,
internet: knicholas@uoknor.edu

Indoor Air Quality, Ventilation and Energy Conservation in Buildings
2nd International Conference
10-12 May 1995
Montreal, Canada
Contact: Fariborz Haghighat, Centre for Building Studies, Concordia University, 1455 de Maisonneuve Blvd. W., Montreal, Quebec, H3G 1M8 Canada, Tel: +1 514 848 3200, Fax: +1 514 848 7965

9th European Simulation Multiconference
5-7 June 1995
Prague, Czech Republic
Contact: The Society for Computer Simulation International, European Simulation Office, c/o Philippe Geril, University of Ghent, Coupure Links 653, B-9000 Ghent, Belgium,
Tel: +32 9 233 77 90, Fax: +32 9 223 49 41,
email: Philippe.Geril@rug.ac.be

IAI Indoor Air International Conference
Scientific and Regulatory Aspects of Air Quality Management
7-9 June 1995
SEC Conference Centre, St Petersburg, Russia
Contact: Conference Secretariat, Association for Air Environment, Research Institute of Industrial and Marine Medicine, Y Gagarin Av, 67, St Petersburg 196143, Russia,
Tel: +7 812 127 2000, Fax: +7 812 126 7583

International symposium
Indoor Air Quality in Practice: Moisture and Cold Climate Solutions
19-21 June 1995
Oslo, Norway
Contact: Ms Lise Olaussen, Norwegian Society of Chartered Engineers, Dr Maudsgt. 15, PO Box 2312, Solli, N-0201 Oslo, Norway,
Fax: +47 22 94 75 02
Topics: The main sessions are as follows: 1. Materials and construction, 2. Indoor air quality and health aspects, 3. Identification, control and remediation, 4. Annual costs versus investment costs.

International Building Performance Simulation Association
Fourth International Conference
14-16 August 1995
Madison, Wisconsin, USA
Contact: Conference Secretariat, John Mitchell, Professor, University of Wisconsin, 1500 Johnson Drive, Madison, WI 53706-1687, USA,
Tel: +1 608 262 5972, Fax: +1 608 262 8464,
email: mitchell@engr.wisc.edu

ISES 1995 Solar World Congress
In Search of the Sun
9-16 September 1995
International Conference Centre, Harare, Zimbabwe
Contact: In search of the sun, PO Box 2851, Harare, Zimbabwe,
Tel: 263-4 730707, Fax: 263-4 730700,
email: xcarelse@zimbix.uz.zw

Healthy Buildings '95
an international conference on healthy buildings in mild climates
11-14 September 1995
Milan, Italy
Contact: Conference Organising Coordinator, Dr Maria Grazia Colombo, International Centre for Pesticide Safety, Via Magenta, n. 25, 20020 Busto Garolfo (Milano), Italy,
Tel: +39 331 568091/499371-2, Fax: +39 331 568023

Tsinghua - HVAC '95
2nd International Symposium on Heating, Ventilation and Air Conditioning
23-25 September 1995
Beijing, China
Contact: Prof Yi jiang, Secretariat of the Symposium, Dept of Thermal Engineering, Tsinghua University, 100084, Beijing, P R China,
Tel: +86 1 2561144 ext 2746, Fax: +86 1 2545093

4th UK National Conference on Heat Transfer
26-27 September 1995
Manchester Conference Centre, UK
Contact: Hazel Anderson, Conference Services Department C510, Institution of Mechanical Engineers, 1 Birdcage Walk, London SW1H 9JJ, UK
Tel: 0171 973 1317, Fax: 0171 222 9881
Topics: The session headings are as follows: Radiation and combustion; convection; conduction; two-phase flow and condensation; boiling (pool and flow); numerical techniques and modelling; heat exchangers and heat transfer augmentation; applied heat transfer and measurement.

7DBMC
7th International Conference on the Durability of Building Materials and Components
19-23 May 1996
Stockholm, Sweden
Contact: Executive Secretariat 7DBMC, Division of Materials Technology, Department of Built Environment, Royal Institute of Technology, PO Box 88, S-801 02 Gavle, Sweden,
Tel: +46 26 14 78 00, Fax@ +46 26 14 78 01

AIVC Publications Order Form

Name .... Date ....

Address (including country) ....

....

....

Telephone/Fax ....

Price and availability: please see notes at foot of page

Periodicals[1]	
[ ]	Air Infiltration Review
[ ]	Recent Additions to AIRBASE
[ ]	Please add me to your mailing list

Technical Notes[2]			
[ ] Applications Guide*		[ ] TN24*	[ ] TN31*
[ ] Handbook*		[ ] TN25*	[ ] TN32*
[ ] TN11*	[ ] TN17*	[ ] TN26*	[ ] TN33*
[ ] TN13*	[ ] TN20*	[ ] TN27*	[ ] TN34*
[ ] 13.1*	[ ] TN21*	[ ] TN28*	[ ] TN35
[ ] TN16*	[ ] TN23*	[ ] 28.2*	[ ] TN36

Conference Proceedings		
[ ]	10th	£30
[ ]	11th	£35
[ ]	12th	£50
[ ]	13th	£50
[ ]	14th	£50
[ ]	15th	£50

Annotated Bibliographies[2]	
[ ]	BIB1
[ ]	BIB2
[ ]	BIB3

IEA Information	
[ ]	IEA News
[ ]	IEA Publications List
[ ]	Add to mailing list?

[ ] TN37	[ ] TN40	[ ] TN43	[ ] TN46
[ ] TN38	[ ] TN41	[ ] TN44	
[ ] TN39	[ ] TN42	[ ] TN45	

Literature Lists - No.s:

[ ]	AIRBASE bibliographical database+ £176.25
[ ]	Updates £30.00 (annually or quarterly)

I enclose a cheque drawn on a UK bank, and made payable to Oscar Faber Partnership / Please invoice me / Please debit my Master/Visa card (delete as appropriate):

for the sum of: £ ....

Signed ....

Master/Visa Card No ....

Expiry Date ....

1 Air Infiltration Review: Participants: free, Non participants: £25 per annum.
Recent Additions: *Participants only*: free.

2 Technical Notes 35 onwards and the annotated bibliographies are available *to participants only* - free of charge
*Technical Notes up to 34 are are available on loan, as a microfiche, or for £15.00 in hard copy.
Please state whether photocopy ☐ or microfiche ☐ for Technical Notes up to 34.

- All prices are in UK pounds Sterling

+ Price inclusive of UK Value Added Tax (VAT) at 17.5%. *Available to participants only.*

- **Participating countries** are: Belgium, Canada, Denmark, Finland, France, Germany, Netherlands, New Zealand, Norway, Sweden, Switzerland, UK and USA.

3rd fold (insert in Flap A)

1st fold

Library
Air Infiltration and Ventilation Centre
University of Warwick Science Park
Sovereign Court
Sir William Lyons Road
Coventry CV4 7EZ
Great Britain

2nd fold (Flap A)

AIVC Publications

PERIODICALS

Air Infiltration Review. Quarterly newsletter containing topical and informative articles on air infiltration research and application.

Recent Additions to AIRBASE. Quarterly bulletin of abstracts added to AIRBASE, AIVC's bibliographic database.

AIRBASE DATABASE

AIRBASE the AIVC's bibliographical database, containing over 7,000 records on air infiltration, ventilation and related areas, is available as a diskette package for your personal computer.

TECHNICAL NOTES

Applications Guide (1986) Air Infiltration Calculation Techniques
Handbook (1983) Air infiltration control in housing
TN 11 (1983) Validation and comparison of mathematical models
TN 13 (1984) Wind pressure data requirements
TN 13.1 (1984) 1984 Wind Pressure Workshop Proceedings
TN 16 (1985) Leakage Distribution in Buildings
TN 17 (1985) Ventilation Strategy - A Selected Bibliography
TN 20 (1987) 'Airborne moisture transfer: workshop proceedings
TN 21 (1987) Review and bibliography of ventilation effectiveness
TN 23 (1988) Inhabitants' behaviour with regard to ventilation
TN 24 (1988) AIVC Measurement Techniques Workshop
TN 25 (1989) Subject analysis of AIRBASE
TN 26 (1989) IEA Annex IX 'Minimum ventilation rates
TN 27 (1990) Infiltration and leakage paths in single family houses
TN 28 (1990) A guide to air change efficiency
TN 28.2 (1991) A guide to contaminant removal effectiveness
TN32 (1991) Reporting guidelines for airflows in buildings
TN33 (1991) A review of building air flow simulation
TN34 (1991) Air flow patterns: measurement techniques.'
TN35 (1992) Knoll B 'Advanced ventilation systems - state of the art and trends.'
TN 36 (1992) Limb M J 'Airgloss Air Infiltration Glossary'.'
TN 37 (1992) Liddament M W, 'A Strategy for Future Ventilation Research and Applications',
TN 38 (1992) Limb M J 'AIRGUIDE: Guide to the AIVC's Bibliographic Database'.
TN 39 (1993) Liddament M W "A Review of Ventilation Effeciency".
TN 40 (1993) Kendrick J F, "An Overview of Combined Modelling of Heat Transport and Air Movement".
TN 41 (1993) Wilson D and Walker I, "Infiltration Data from the Alberta Home Heating Research Facility".
TN 42 (1994) Limb M J, "Current Ventilation and Air Conditioning Systems and Strategies".
TN 43 (1994) Limb M J "Ventilation and Building Airtightness: an International Comparison of Standards, Codes of Practice and Regulations".
TN 44 (1994) Orme M S, " An Analysis and Data Summary of the AIVC's Numerical Database".
TN45 (1994) Irving S, "Air-to-Air Heat Recovery in Ventilation".
TN 46 (1995) Limb M J, "1994 Survey of Current Research"
(Unlisted technical notes have been superceded)

ANNOTATED BIBLIOGRAPHIES

(Participants only - price see order form)
BIB1 (1993) Ventilation and infiltration characteristics of lift shafts and stair wells
BIB2 (1994) Garage Ventilation: Summarises research into the health, energy and design aspects of the various systems used in garage ventilation.
BIB3 (1994) Natural ventilation: Covers the main elements of natural ventilation research, the fundamental equations, driving forces and associated factors, as well as useful reports which focus on modelling and calculating natural ventilation air flows.

AIVC CONFERENCE PROCEEDINGS

AIVC Conference Proceedings nos 1-9 are available as individual papers, or in microfiche form. Details of contents can be forwarded on request.
10th 'Progress and trends in air infiltration and ventilation research' Espoo, Finland, 1989;
11th 'Ventilation System Performance' Belgirate, Italy, 1990;
12th 'Air Movement and Ventilation Control within Buildings', Ottawa, Canada, 1991, 3 volumes.;
13th 'Ventilation for Energy Efficiency and Optimum Indoor Air Quality', France, 1992;
14th 'Energy Impact of Air Infiltration and Ventilation', Denmark, 1993
15th 'The role of ventilation', Buxton, UK, 1994

LITERATURE LISTS

(Available to participants only - free of charge)
1) Pressurisation - infiltration correlation: 1. Models.
2) Pressurisation - infiltration correlation: 2. Measurements.
3) Weatherstripping windows and doors.
4) Caulks and sealants.
5) Domestic air-to-air heat exchangers.
6) Air infiltration in industrial buildings.
7) Air flow through building entrances.
8) Air infiltration in commercial buildings.
9) Air infiltration in public buildings.
10) Carbon dioxide controlled ventilation.
11) Occupancy effects on air infiltration.
12) Windbreaks and shelterbelts.
13) Air infiltration measurement techniques.
14) Roofs and attics.
15) Identification of air leakage paths.
16) Sick buildings.
17) Flow through large openings.
18) Control of cross contamination from smokers.
19) Location of exhausts and inlets.
*For list of participating countries see back page.

IEA ENERGY CONSERVATION IN BUILDINGS PROGRAMME - REPORTS FROM OTHER ANNEXES

IEA Energy Conservation News Twice yearly newsletter of the IEA Energy Conservation in Buildings Programme, contains topical updates on the current projects, and news of conferences, workshops, etc.

Publications A publications brochure for the various annexes can be provided on request free of charge.

Representatives and Nominated Organisations

Belgium

*P. Wouters, Belgian Building Research Institute (WTCB/CSTC), rue de la Violette,21-23, 1000 Brussels, Belgium. Tel: + 32 2-653-8801 Fax: + 32 2-653-0729

P. Nusgens, Université de Liège, Laboratoire de Physique du Bâtiment, Avenue des Tilleuls 15-D1, B-4000 Liège,Belgium. Tel: + 32 41 66 56 74 Fax: + 32 41 66 57 00

Canada

*M. Riley, Buildings Group, Energy Efficiency Division, Efficiency and Alternative Energy Branch, Energy, Mines and Resources Canada, Ottawa, Ontario, K1A 0E4 Canada Tel: + 1 613-996-8151 Fax: + 1 613-996-9416

J. Shaw, Inst. for Research in Construction, National Research Council, Ottawa, Ontario, Canada K1A 0R6 Tel:+ 1 613-993-1421 Fax: + 1 613 954 3733

Duncan Hill, Research Division, Canada Mortgage and Housing Corporation, Montreal Road, National Office, Ottawa, Ontario, Canada K1A 0P7 Tel: + 1 613-748-2309 Fax:+ 1 613 748 2402

Denmark

*O. Jensen, Danish Building Research Institute, P.O. Box 119, DK 2970 Hørsholm, Denmark. Tel: + 45-42-865533 Fax: + 45-42-867535

P.F. Collet, Technological Institute, Byggeteknik, Post Box 141, Gregersensvej, DK 2639 Tastrup, Denmark. Tel: + 45 42-996611 Fax: + 45-42-995436

Finland

*J Sateri, Laboratory of Heating and Ventilation, Helsinki University of Technology, Otakaari 4A, FIN-02150, Espoo, Finland. Tel: + 358 0 4564710, Fax: + 358 0 455 2408

France

*P Hérant, ADEME, Route des Lucioles, 06565 Valbonne Cedex, France Tel: + 33 93 95 79 00 Fax: + 33 93 65 31 96

Ph. Duchêne-Marullaz, CSTB, 84 Ave. Jean Jaurès, BP 02 Champs sur Marne, 77421 Marne la Vallée, Cedex 2, France Tel: + 33-1 64 68 83 13 Fax: + 33-1 64 68 83 50

Germany

*Prof. Dr.-Ing. F. Steimle, Universität Essen, Universitätsstr. 15, 45141 Essen, Germany, Tel: + 49 201 183 2600, Fax: + 49 201 183 2584

J. Gehrmann, Projektträger BEO - Biologie, Energie, Okologie, KFA Jülich, Postfach 19 13, 52425 Jülich, Germany Tel: + 49 2461/614852

G Mertz, Fachinstitut Gebäude Klima e.V., Danziger Strasse 20, 74321 Bietigheim-Bissingen, Germany Tel: + 49 7142 54498 Fax: + 49 7142 61298

Netherlands

*W.F. de Gids, TNO Building and Construction Research, Dept of Indoor Environment, Building Physics and Systems, P.O. Box 29, 2600 AA Delft, Netherlands, Tel: + 31 15 608608 (Direct: + 31 15-608472) Fax: + 31 15-608432

New Zealand

*M. Bassett, Building Research Association of New Zealand Inc (BRANZ), Private Bag, Porirua, New Zealand. Tel: + 64-4-2357600 Fax: + 64 4 2356070

Norway

*J.T. Brunsell, Norwegian Building Research Institute, Forskningsveien 3b, PO Box 123, Blindern, N-0314 Oslo 3, Norway. Tel: + 47 22-96-55-00 Fax: + 47-22-965542, e-mail jbrunsel@ulrik.uio.no

H.M. Mathisen, SINTEF,Division of App Thermodynamics, N-7034 Trondheim, Norway. Tel: + 47 73-593000 Telex: 056-55620

Sweden

*J. Kronvall, J&W Consulting Engineers AB, Slagthuset, S-21120 Malmo, Sweden, Tel: + 46 40108200, Fax: + 46 40108201

J Lagerström, Swedish Council for Building Research, Sankt Goransgatan 66, S-112 33, Stockholm, Sweden Tel: + 46 8-6177300 Fax: + 46 8-537462

Switzerland

*V. Dorer, EMPA, Section 175, Ueberlandstrasse, CH 8600 Dübendorf, Switzerland. Tel: + 41 1-823-4789 Telex: 825345 Fax: + 41 1-821-6244

UK

*MDAES Perera, Environmental Systems Division, Building Research Establishment, Garston, Watford, WD2 7JR , UK Tel:+ 44(0)1923 664486 Telex: 923220 Fax: + 44(0)1923 664095, e-mail pererae@bre.co.uk

S. Irving (Operating Agent), Oscar Faber Consulting Engineers, Marlborough House, Upper Marlborough Road, St. Albans, Herts, AL1 3UT, Great Britain. Tel: + 44(0)181-7845784 Telex: 889072 Fax: + 44(0)181-7845700

USA

*M. Sherman, Indoor Air Quality Division, Building 90, Room 3074, Lawrence Berkeley Laboratory, Berkeley, California 94720, USA. Tel: + 1 510/486-4022 Telex: 910-366-2037 Fax: + 1 510 486 6658 e-mail:MHSherman@lbl.gov

A. Persily, Building Environment Division, Center for Building Technology, Building 226, Room A313, National Institute for Standards and Technology, Gaithersburg MD 20899, USA. Tel: + 1 301/975-6418 Fax: + 1 301/975-4032

J. Talbott, Department of Energy, Buildings Division, Mail Stop Ce-131, 1000 Independence Avenue S.W., Washington D.C. 20585, USA. Tel: + 1 202/586 9445 Fax: + 1 202 586 4529/8134

*Steering Group Member

AIVC

Head of Centre Martin W Liddament

Published by
Air Infiltration and Ventilation Centre
University of Warwick Science Park
Sovereign Court
Sir William Lyons Road
Coventry CV4 7EZ, UK

Tel: + 44(0)1203 692050
Fax: + 44(0)1203 416306
e-mail: airvent@AIVC.org

Operating agent for IEA is Oscar Faber Consulting Engineers, UK