

# Air Infiltration Review

a quarterly newsletter from the IEA Air Infiltration and Ventilation Centre

International Energy Agency - AIVC

Vol. 18, No.4, September 1997

## ASHRAE Summer Meeting Boston (28th June - 2nd July)

Report by Martin W. Liddament, Head of Air Infiltration and Ventilation Centre

### Particles in Buildings - Seminar

The impact of urban particulate pollution on indoor air quality is becoming a growing concern, with new research highlighting the risks to building occupants. Results show that such contaminants can be detrimental to human health and comfort and are an important factor in maintaining acceptable indoor air quality. Current information and research was reviewed at a Seminar.

William Wilson of the United States Environmental Protection Agency presented an overview of particulate contamination and its impact on health. He also reported that new proposed standards were shortly to be published covering particulate concentrations. Early evidence was taken from the London (England) smogs of 1962, which showed a distinct correlation between periods of smog and subsequent peaks in death rate. Since then much more detailed studies have revealed similar correlations between particulate intensity and increased incidences of death.

The significance of particle size on health was stressed. Essentially, particles vary in size from fractions of a micron ( $\mu\text{m}$ ) up to clearly visible material of  $100\mu\text{m}$  or more. Two size ranges have been intro-

duced, in part reflecting the severity of impact on humans. These ranges are:

- 'fine mode' particle range (i.e. particle sizes up to  $2.5\mu\text{m}$ );
- 'course mode' particle range (i.e. greater than  $2.5\mu\text{m}$ ).

Fine mode particles penetrate the deepest levels of the lung (thoracic region). They are difficult for the body to expel and are thought to cause most damage. Hitherto, much research and many standards have been based on 'PM<sub>10</sub>'s, these being 'respirable' particles of size up to  $10\mu\text{m}$  (i.e. they penetrate the lung). These show strong correlation with health but more recent research suggest that it is the 'PM<sub>2.5</sub>' (i.e. up to  $2.5\mu\text{m}$ ) component that has the greatest adverse health effect. Existing research, including that of the 'Harvard Six City Study' shows that each  $10\mu\text{g}/\text{m}^3$  of PM<sub>10</sub> results in a measurable increment in death rate (present standards for PM<sub>10</sub>'s are set at  $50\mu\text{g}/\text{m}^3$ ).

A study in Riverside, California, has focused on the sources of particulates in the home (Figure 1). This shows that approximately 76% of PM<sub>2.5</sub>'s are derived from the outside air whereas the figure for PM<sub>10</sub>'s is 66%. 'Other' indoor sources include insect fragments, especially in the PM<sub>10</sub> range. The ambient in-

#### In this issue

New Products - MSP Cleanroom Fogger<sup>TM</sup> and Portable Cleanroom Fogger<sup>TM</sup> .....page 5

AIVC Website Update .....page 6

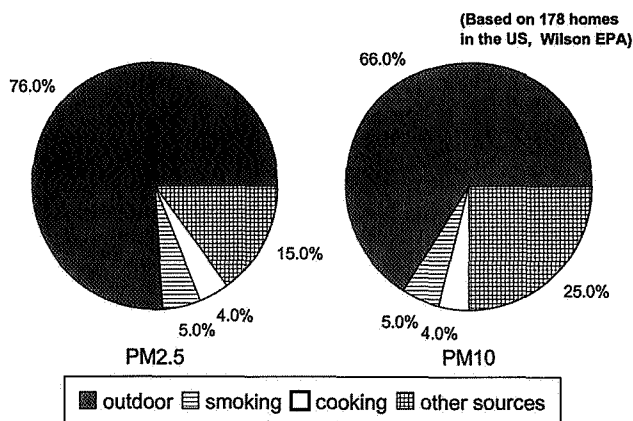
Passive Stack Ventilation with Heat Recovery.....page 7

Publications Catalogue .....page 11

Forthcoming Conferences.....page 15

door to outdoor ratio is shown to depend on the air change and deposition rates. More PM<sub>2.5</sub> gets into the building than PM<sub>10</sub>. At about 2 air changes/hour PM<sub>2.5</sub> concentrations approaches about three quarters or more of the outdoor value.

### Sources of Indoor Particles



Following this presentation, Eileen Abt of the Harvard School of Public Health in Boston talked about an ongoing study on the characterisation of particulate sources in four urban (non-smoking) homes. Currently, monitoring of the indoor environment has taken place in each home, for 6 day periods in Winter and Spring. Measurements have included:

- particles 0.02-10µm, PM<sub>2.5</sub> and PM<sub>10</sub> (continuous and integrated, indoor and outdoor)
- particles PM<sub>2.5</sub> and PM<sub>10</sub>
- air change rate (SF<sub>6</sub> Tracer Gas)
- temperature
- relative humidity
- wind speed and direction

An initial analysis of diurnal results shows that in the early morning (3 a.m.), the indoor and outdoor concentration of particles is similar. During the day, the indoor concentration becomes influenced by household activities, especially cooking (by gas) and vacuum cleaning.

Barbara Turpin of Rutgers Cook College described her current research into monitoring personal expo-

sure to fine particulate matter. By using personal exposure monitors and observing the movements of volunteers, she is assessing the contributing sources of particles to individuals. Personal exposure (X) is evaluated from:

$$X = \frac{\sum x_i t_i}{\sum t_i} \mu\text{g} / \text{m}^3$$

where  $x_i$  = exposure over time  $t_i$

Results show that between 50-80% of inhaled fine particles are from outdoor sources.

Also while the average exposure to PM<sub>10</sub>'s to a community depends on the ambient pollution, individual exposure is highly variable, depending very much on the micro climate and the individuals' activities. Barbara Turpin further expressed a need to chemically characterise individual exposure, for example to specific pollutants such as:

- metals (chromium, cadmium, lead, arsenic, vanadium)
- hydrocarbons
- other materials including sulphates, ammonium compounds, Teflon, silicates, amides.

She stressed that the techniques being developed in this study would have important applications in future pollutant health effect and personnel monitoring studies.

David Pui of the University of Minnesota went on to characterise particulate sources based on indoor and outdoor measurements. Typical fine particles included organic carbon, sulphate and soot whereas coarse materials included soil, minerals, nitrates and road dust.

## New Research Topics

Various new ASHRAE research topics have been proposed. Those for which outline Work Statements have been prepared include:

# 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.

## **Integrating Current ASHRAE Results on Air Flow Around Buildings into Practical Design Guidelines**

Air flow around buildings has many important implications, for example in terms of pollutant transport, air infiltration, and natural ventilation design. An update was covered by a seminar on what designers need to account for. Currently, many design procedures for incorporating knowledge about outdoor air flow are inadequate. To address this a proposal has been prepared aimed at the translation of research results and existing knowledge into practical calculation techniques that can be used by building designers. The intention is to:

- summarise current (ASHRAE) research;
- produce updated simplified design tools;
- identify areas of building air flow requiring further research.

## **Exhaust Contamination of Hidden Vs. Visible Air Intakes**

It has become common for designers to place air intakes on the walls of buildings, just below the roof, rather than on the roof itself. One of the aims is to 'hide' the intake from roof level exhausts. Although there is a perception, among designers, that inlet air is likely to be less contaminated, more systematic information is needed. The intention of this project is to:

- analyse the characteristics of 'diluted' plumes;
- determine the performance of a 'hidden' intake in relation to a roof exhaust and an identical exhaust on an adjacent wall;
- evaluate the significance of the building shape and size.

## **Heat Transfer During Residential Infiltration and Exfiltration**

The purpose of this proposal is to evaluate the impact of thermal coupling between infiltrating air and insulating layers (i.e. assessing the impact of any infiltration 'heat recovery' under normal conditions of air infiltration). The objective is to measure the energy impact of infiltration/exfiltration in real yet typical dwelling units. A reliable technique needs to be developed for measuring the heat transfer between infiltrating and exfiltrating air and conduction heat flows through residential building envelopes. Based on the experimental results, the impact of air infiltration on load calculations will be provided.

## **Simplified Models for Room Air and Air Contaminant Distribution**

Understanding the air and air contaminant in rooms is important for the design and operation of room air distribution systems. While computational fluid dynamic models provide comprehensive detail they are generally too complicated to be used directly for design. This seminar reviewed simplified models for predicting air flow. Per Heiselberg of Aalborg university, Denmark considered air movement in terms of indi-

vidual flow elements. These included:

- air jets described by semi empirical equations based on laboratory measurements;
- plumes above heat sources;

In 'normal' size enclosures flow throughout the space is dominated by each flow element. In 'large' enclosures flow elements tend only to affect flow locally. Examples were illustrated in which elements could be treated as non-interacting (e.g. displacement flow) and in which simple zonal models could be used to combine flow elements.

Qingyan Chen of MIT described a simplified zero equation turbulence model, based on a 'local' mixing length. Computational time was reduced to 1/100th of that needed for a conventional k-ε approach. This resulted in a typical three dimensional CFD problem being solved within 10 minutes on a PC with a minimum loss of performance.

Alexander Zhivov of the University of Illinois described the use of multi-zone heat and mass balance equations for practical applications while John Shaw of the NRC in Canada presented a review of simplified models.

## **Seminar on Sensory Panels and the Assessment of Indoor Air Quality**

Developments in odour perception were reviewed by Ole Fanger (Technical University, Denmark), James Woods (Virginia Tech, USA), Jarrel Wenger (Johnson Controls, USA) and Diotimi von Kempster (DVK, Germany). Discussion covered the need for sensory panels, the significance of odour as a pollutant and the difficulties associated with defining the perception of comfort. Jarrel Wenger described progress with an 'electronic' nose which was tested against a 'trained panel'. Various complexities of sensory arrays were used covering the simultaneous measurement of common gases and vapours, particulates, VOC's, humidity, noise, light intensity, temperature, radiation, air velocity and turbulence. In many instances, panel judgements were found to be concurrent with sensor readings but, in price, the equipment was prohibitively expensive. The best single instrument was found to be an infra-red detector optimised for methyl methacrylate. Correlation between carbon dioxide concentration and the sensory panel was found not to be good. A reduced 'optimal' set of eleven sensors was found to be a fairly reliable indicator of odour and it was thought that this could be further reduced to seven sensors.

## **Other Symposia and Technical Sessions**

Air related Technical Sessions and Symposia for which papers are published, (and referenced in *AIR-BASE*) included:

- demand controlled ventilation and IAQ;
- fire in atria and other large spaces;

- IAQ control strategies and CO<sub>2</sub> monitoring (poster session).

## Developments to ASHRAE Standard 62 - Call for Members

There is still much on-going activity continuing with the updating of Standard 62 on Ventilation for Acceptable Indoor Air Quality. Sessions included forums entitled 'should ASHRAE Standards relevant to IAQ be based on health or comfort', 'ASHRAE's role in IAQ' and ASHRAE Standard 62 compliance: central vs local ventilation control.

The Standards Committee approved separating the proposed revision of ANSI/ASHRAE Standard 62-1989 Ventilation for Acceptable Indoor Air Quality into two separate proposed standards. SSPC 62 was redesignated as SSPC 62.1 with the charge of revising portions of Standard 62-1989 that relate to all buildings except low-rise residential buildings. The Standards Committee authorised a new project committee, SPC 62.2P, to revise portions of Standard 62-1989 that relate to low-rise residential buildings. A call for members is announced for this project committee as described below. Experts who are interested in serving on SPC 62.2P are asked to indicate their interest and obtain the necessary forms from the Manager of Standards, ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA 30329-2305.

### SPC 62.2P

## Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

### 1 Purpose.

This standard defines the roles of and minimum requirements for mechanical and natural ventilation systems and the building envelope intended to provide acceptable indoor air quality in low-rise residential buildings.

### 2 Scope

2.1 This standard applies to spaces intended for human occupancy within single-family houses and multi-family structures of three stories or fewer above grade, including manufactured and modular houses. This standard does not apply to transient housing such as hotels, motels, nursing homes, dormitories or jails.

2.2 This standard applies to new buildings, additions to existing buildings, and some changes to existing buildings.

2.3 This standard considers chemical, physical and biological contaminants that can affect air quality. Thermal comfort requirements are not included in this standard (see ASHRAE Standard 55).

2.4 While acceptable indoor air quality is the goal of this standard, it will not necessarily be achieved even if all requirements are met:

a) because of the diversity of sources and contaminants in indoor air and the range of susceptibility in the population;

b) because of the many other factors that may affect occupant perception and acceptance of indoor air quality, such as air temperature, humidity, noise, lighting and psychological stress;

c) if the ambient air is unacceptable and this air is brought into the building without first being cleaned. (Cleaning of ambient outdoor air is not required by this standard.); or

d) if the system(s) are not operated and maintained as designed.

## ASHRAE Symposium "Ventilation in Light Commercial Buildings" - Call for Papers

It is proposed to hold a symposium on ventilation in light commercial buildings at the Chicago ASHRAE Meeting in January 1999.

The purpose of this symposium is to focus on recent activities covering air change rate, airtightness and air quality relating to such buildings. Building types include:

- shopping malls and retail outlets
- warehouses
- small factory units
- other similar structures

Abstracts of papers are required now and should be sent to Martin Liddament at the AIVC.

## Don Colliver - Former AIVC Visiting Specialist becomes ASHRAE Vice President

Professor Don Colliver, visiting specialist to the AIVC in 1995 was elected as a Vice President to ASHRAE. During his time at the AIVC Don undertook work on the effect of climate on the energy impact of ventilation. This work (documented in AIVC Technical Note 47) involved the analysis of long-term hourly weather data from a number of European and American locations. The intent was to determine the psychrometric process theoretical heating, cooling and moisture removal energy requirements for a constant mass of airflow per hour. This was performed for a range of temperature and humidity setpoints.

### For further information:

For further information about any of these ASHRAE activities, please contact Martin Liddament at the AIVC

# New Products - MSP Cleanroom Fogger™ and Portable Cleanroom Fogger™

Two related products from MSP Corporation are able to assist with airflow visualisation. The Model 2000 Cleanroom Fogger is a high density fog generator designed for airflow visualisation in cleanrooms. High purity de-ionised water is vaporised to form steam in a stainless steel boiler. The steam is then injected into a stainless steel Dewar containing liquid nitrogen, where the hot steam causes the liquid nitrogen to vaporise, which in turn quenches the steam to form a non-contaminating room-temperature fog of de-ionised water droplets. This fog is extremely dense. A portable version of the Cleanroom Fogger is available (Model 2010), with a lower boiler capacity than the standard model, but still operating on the same principles. Although marketed specifically for cleanroom applications, it is conceivable that this product may generate wider interest from ventilation researchers and system designers. Uses of the Fogger may include:

- locating dead spots,
- airflow balancing,
- characterisation of exhaust flow and turbulence,
- finding routes of air infiltration, and
- long distance airflow tracking.



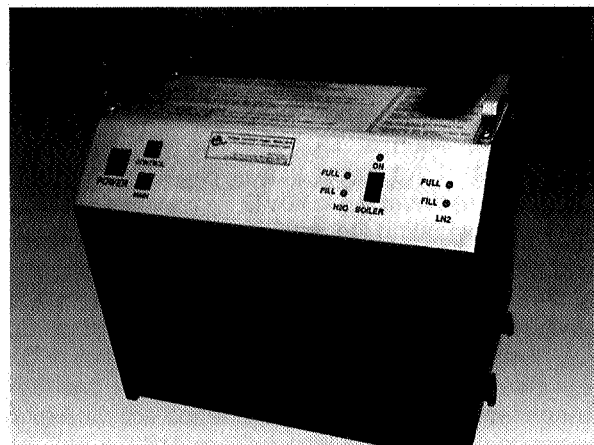
## Contact Information

### *In Europe:*

Alliance Sales (Europe) Ltd, Kestrel House, Alma Road,  
Romsey, Hants, SO51 8ED, England  
Tel: +44 (0)1794 518183 Fax: +44 (0)1794 518490  
Email: [alliance@dial.pipex.com](mailto:alliance@dial.pipex.com)  
Web: <http://www.european-business-team.com/>

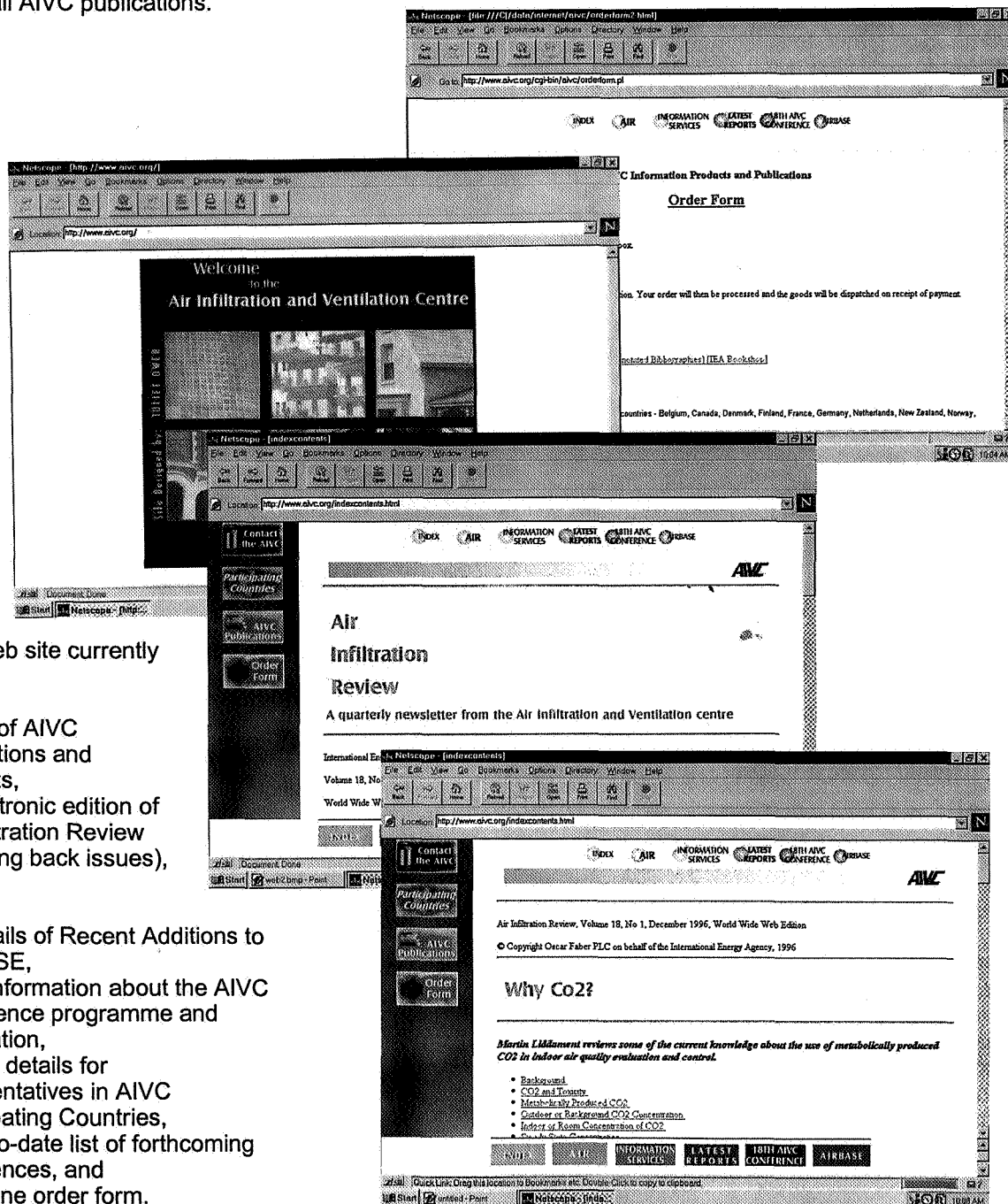
### *Elsewhere:*

MSP Corporation, 1313 Fifth Street SE, Suite 206, Min-  
neapolis, Minnesota 55414, USA  
Tel: +1 612 379 3963 Fax: +1 612 379 3965



# AIVC World Wide Web Site Relunched

This summer has seen a dramatic transformation of the AIVC's World Wide Web site, thanks to the efforts of Juliet Owen, a Design Studies student from Nottingham Trent University in the UK. She has spent eight weeks at the Centre this summer applying her artistic and design skills to the existing Web site, as part of a student project. As a result, the site has been improved considerably in its layout and design. In particular, 'frames' have been added, to allow easier navigation around the site, whilst still retaining a 'no-frames' option for users without frames-enabled Web browsers. (For those considering upgrading to frames-enabled browsers, examples include Netscape Navigator, obtainable from <http://www.netscape.com/> and Microsoft Internet Explorer, which can be found at <http://www.microsoft.com/>.) Navigation buttons have been added in fixed toolbars to make it easier to find pages. Another major addition to the Web site, also designed by Juliet, is an on-line order form for all AIVC publications.



The AIVC Web site currently includes:

- details of AIVC publications and products,
- an electronic edition of Air Infiltration Review (including back issues),
- full details of Recent Additions to AIRBASE,
- latest information about the AIVC Conference programme and registration,
- contact details for representatives in AIVC Participating Countries,
- an up-to-date list of forthcoming conferences, and
- an on-line order form.

*The AIVC staff would like to thank Juliet for her hard work and wish her every success in her future studies.*

*Please visit us at <http://www.aivc.org/>.*

# Passive Stack Ventilation with Heat Recovery

by S B Riffat and G Gan

Institute of Building Technology, Department of Architecture and Building Technology,  
University of Nottingham, UK

## Introduction

Ventilation accounts for 30% or more of space conditioning energy demand but as much as 70% of this energy can be recovered by the use of ventilation heat recovery systems [1]. Until now, effort has mainly been devoted to the design and development of heat recovery systems for mechanically-ventilated buildings. However, most domestic buildings are naturally ventilated and little consideration has been given to heat recovery from these buildings. A crucial parameter limiting the use of heat recovery with natural ventilation is pressure loss. The total pressure loss through a natural ventilation system so that sufficient air pipes would have the potential to provide substantial heat recovery without significant pressure loss.

A heat-pipe heat recovery unit is a heat exchanger consisting of externally-finned sealed pipes using a working fluid such as methanol or water. The unit is divided into two sections, i.e., the evaporator and the condenser, for heat exchange between exhaust and supply air (see Figure 1). In addition to low flow resistance, a heat-pipe heat exchanger has a number of other advantages over conventional heat exchangers such as high reliability, no cross-contamination, compactness and suitability for both heating and cooling.

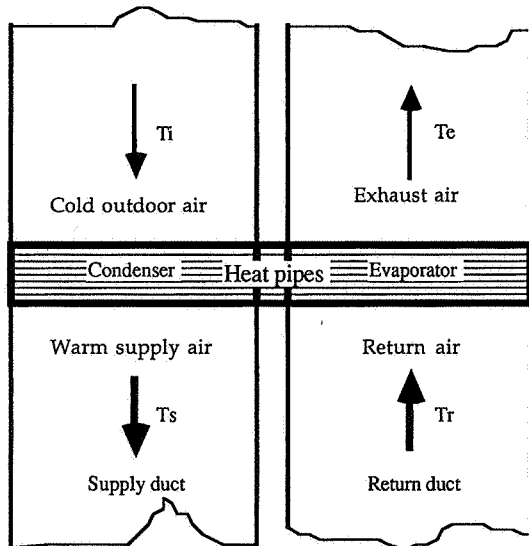


Figure 1: Schematic diagram of heat-pipe heat recovery.

The objective of this work is to assess the performance of heat-pipe heat recovery units for naturally-ventilated buildings. The effectiveness of four heat-pipe units was measured in a two-zone chamber. The pressure loss characteristics of the units

were determined by computational fluid dynamics (CFD).

## Heat Pipes

Four types of heat-pipe heat recovery units were constructed and tested. Figure 2 shows the cross-section of the heat pipes. The working fluid in the pipes was methanol with an operating temperature range from  $-40^{\circ}\text{C}$  to  $100^{\circ}\text{C}$ .

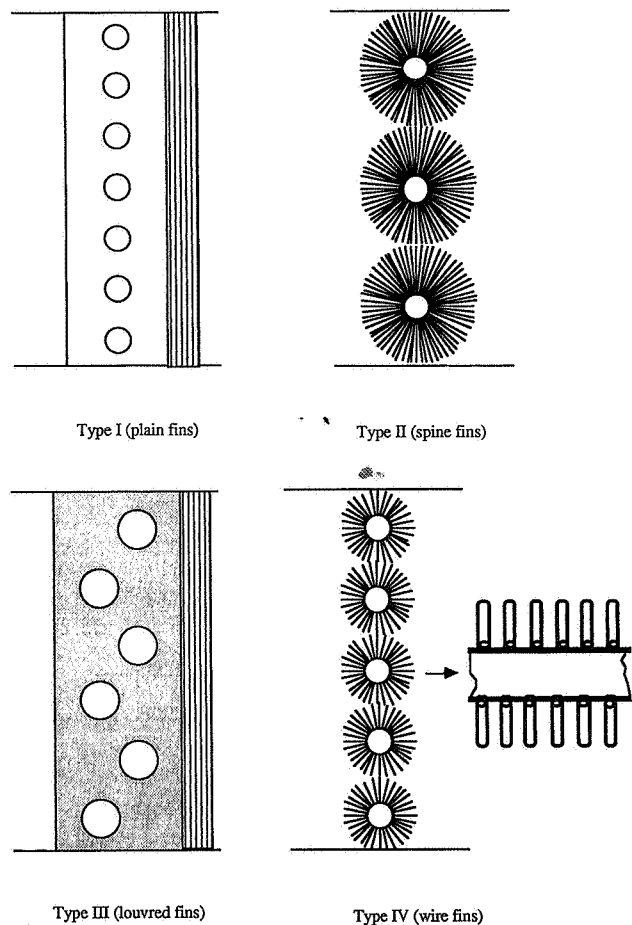


Figure 2: Cross-section of heat pipes.

The first heat recovery unit (Type I) consisted of a bank of seven externally finned heat pipes. Each pipe was 0.0127 m in outside diameter and 0.45 m in length with 72 continuous plain fins (0.215 m long, 0.048 m high and 0.45 mm thick) on both the condenser and evaporator sections. The cross-sectional area of both the condenser and evaporator sections was 0.215 x 0.215 m. The total surface area of each finned pipe including fins and exposed pipe was 0.196 m<sup>2</sup>. The whole unit was made of copper.

The second type heat pipe had cylindrical spine fins. The fins were made of copper wire. The unit with this type of fin consisted of three heat pipes of the same size and material as for Type I. There were eight continuous rows of fins on each of these pipes. Each row had about 300 spine fins and each spine fin was 0.7 mm in diameter and 30 mm long. The estimated total surface area of the spine fins of each heat pipe was 0.158 m<sup>2</sup>, which is about 19% less than that of the continuous plain fins.

The third type of heat recovery unit was made of two rows of staggered heat pipes. Each row consisted of three heat pipes. Each pipe was 18 mm in diameter and 365 mm in length with 70 continuous louvred aluminium fins on both the condenser and evaporator sections. Each fin was 180 mm long and 60 mm high and had 96 louvres with 2 mm spacing and 0.65 mm gap. The cross-sectional areas of the condenser and evaporator sections were 180 x 180 mm and 175 x 180 mm, respectively. The total surface area for heat transfer to the evaporator section was 1.5418 m<sup>2</sup>; this is about 8% more than that for Type I heat pipes.

The fourth type of heat recovery unit was made of five in-line heat pipes with wire fins. Each pipe was 19.05 mm in diameter and 450 mm long with 34.5 turns of copper wire fins on both the condenser and evaporator sections. Each turn of fins had 65 loops of wire 0.65 mm in diameter and 12 mm high. The cross-sectional area of the unit is the same as that of the first type of heat pipe. The total surface area for heat transfer of the evaporator or condenser section was 0.6035 m<sup>2</sup>; this is less than half of the first type.

## Effectiveness of Heat Recovery

The effectiveness of a heat-pipe heat recovery unit for sensible heat exchange between supply and exhaust air of the same flow rate,  $\varepsilon$  (%), is defined as:

$$\varepsilon = \frac{T_s - T_i}{T_r - T_i} \times 100\% \quad (1)$$

where  $T_i$  and  $T_s$  are the temperatures of inlet air before and supply air after the condenser section of heat exchanger in the supply duct (°C) respectively, and  $T_r$  is the temperature of return air before the evaporator section of heat exchanger in the exhaust duct (°C) (see Figure 1).

Measurements of the effectiveness were carried out in a vertical two-zone test chamber with a heat-pipe heat recovery unit [2]. The two-zone test chamber was designed to allow good mixing of supply air with room air in the lower zone and maintain a uniform temperature and concentration of return air in the upper zone and so to ensure the reliability of temperature and air flow measurements. Thermocouples were used to measure temperatures. The air flow rate was measured using the constant-injection tracer-gas method.

Figure 3 shows a comparison of the measured effectiveness for the four types of heat pipes. It can be seen that the rate of heat recovery increases with decreasing air velocity. However, for a given heat recovery unit this does not necessarily increase the total amount of heat recovery (proportional to velocity).

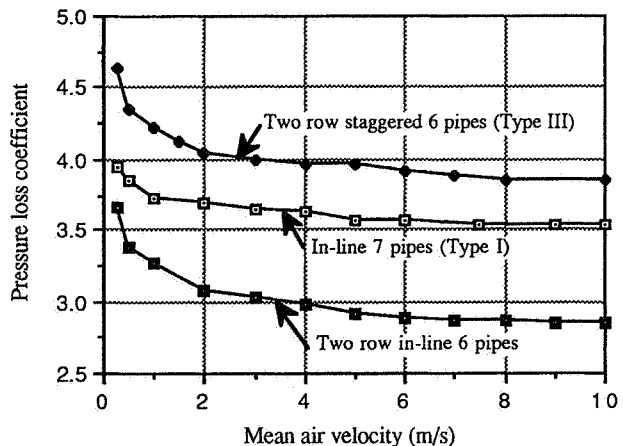


Figure 3: Comparison of effectiveness for four types of heat pipes.

The effectiveness for the spine-fin heat pipes presented in Figure 3 was for seven equivalent heat pipes. The effectiveness for this type of heat recovery unit was much lower than that of plain-fin heat pipes. The main reason for the ineffectiveness of spine-fin heat pipes is the poor thermal contact between fins and pipes, resulting in a high contact resistance.

For the same cross-sectional area, the staggered heat pipes with louvred fins were more effective than plain fins, particularly at lower velocities. This may be attributed mainly to the increased external surface area available for heat transfer per unit cross section (55% more).

The effectiveness of the unit with wire fins was lower than that with plain fins. This is due to the lower external surface area for the wire-fin heat pipes. If the surface area was increased by say 50%, which would still be less than that of the plain-fin heat pipes, the effectiveness would be higher than that of the plain-fin heat pipe unit.

The effectiveness of heat pipes could be increased by employing more than one bank. For example, for Type I heat pipes, the measured heat recovery was between 16% and 17% more efficient using two banks than using one bank. Employing multiple banks of heat pipes would however increase flow resistance and cost of installation. For natural ventilation the resulting pressure loss must be smaller than the driving force so that adequate air flow rates can still be achieved.

## Pressure Loss Across Heat Pipes

The pressure loss across a heat-pipe unit is represented by the pressure loss coefficient ( $k$ ) as follows:

$$k = \frac{\Delta P_s}{\frac{1}{2} \rho V^2} \quad (2)$$

where  $\Delta P_s$  is the static pressure loss across the unit (Pa),  $V$  is the mean velocity of air flowing over the unit (m/s) and  $\rho$  is the air density ( $\text{kg/m}^3$ ).

The pressure loss coefficient for Type I and III heat-pipe units was predicted by means of CFD modelling. The predictions were carried out using the CFD package FLUENT [3]. In the predictions, each row of heat pipes was modelled as one bank of rectangular cylinders such that it had the same free-area ratio and thickness as the real heat pipes. The fins were modelled as uniformly distributed rectangular studs on both sides of heat pipes such that the total cross-sectional area of the studs was the same as the sum of that of the fins.

The pressure loss coefficient was found to decrease with increasing mean air velocity. The pressure loss coefficient for Type I heat pipes can be correlated to velocity between 0.25 and 10 m/s as follows:

$$k = (2.6 + 1.77n) V^{-0.03n^{3/4}}$$

where  $n$  is the number of heat-pipe banks.

The pressure loss at a given velocity can be obtained from the pressure loss coefficient ( $= 1/2k\rho V^2$ ). For example, at a velocity of 0.5 m/s, the pressure loss through a section of one bank of heat pipes is about 0.57 Pa and total pressure loss through the whole unit (both condenser and evaporator sections) is just over 1 Pa. Thus, if the driving pressure available for ventilation is, say, 1 Pa, the mean velocity through the heat-pipe unit should not be more than 0.5 m/s. At a velocity of 1 m/s, the pressure loss through both sections of the unit is 4.5 Pa. Without the wind effect, this would require a stack height of about 10 m at a temperature difference between inlet and exhaust openings of 10 K, or 4 m height at 25 K temperature difference. In naturally-ventilated low-rise buildings, the average driving pressures are unlikely to exceed this value. Therefore, in designing ventilation ducts for housing this type of heat recovery unit, the mean air velocity should be less than 1 m/s.

Figure 4 shows a comparison of pressure loss coefficient for Type I and Type III heat pipes. The predicted loss coefficient for the six staggered 18 mm heat pipes was higher than that for one bank of seven heat pipes of 12.7 mm in diameter despite the porosity (free-area ratio) of the former being higher than that of the latter. When the six pipes were arranged as a two-row in-line bank, the predicted loss

coefficient became lower than that of one bank of seven smaller heat pipes. For example, at a velocity 1 m/s, the predicted loss coefficient for the two-row in-line six pipes was 3.3, compared with 4.2 for the staggered pipes and 3.7 for the in-line seven smaller heat pipes.

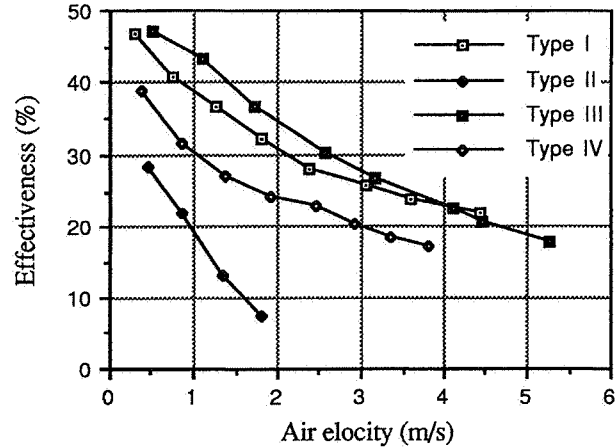


Figure 4: Effect of pipe arrangement on the pressure loss coefficient.

## Conclusions

It is shown that air velocity has a significant effect on the effectiveness of heat-pipe heat recovery. The effectiveness decreases with increasing air velocity. For heat pipes with plain fins, at the same velocity the heat recovery is between 16% and 17% more efficient using two banks than using one bank. Poor thermal contact between fins and pipes can drastically reduce the effectiveness of heat pipes.

At low velocities the pressure loss coefficient decreases with increasing air velocity but the total pressure loss still increases with the velocity. It is recommended that in naturally-ventilated low-rise building, without the wind effect or solar energy, the design mean air velocity should be less than 1 m/s in order for a heat recovery system to function properly.

## Acknowledgement

This project is funded in part by the Commission of European Union under the "JOULE III" Programme.

## References

1. Liddament M W, "A Guide to Energy Efficient Ventilation", AIVC, Coventry, UK, 1996.
2. Riffat S B and Gan G, "Determination of effectiveness of heat-pipe heat recovery for naturally-ventilated buildings", Applied Thermal Engineering (in press).
3. FLUENT User's Guide, Fluent Inc. USA, 1993.

# International Seminar on Air Distribution in Buildings: Airtightness Aspects

Brussels, Belgium, 10th - 11th June 1998

## *Preliminary Announcement*

Air distribution in buildings is generally carried out by ducted systems. To achieve a good performance, various requirements have to be met, including, among others, low friction losses, durability, clean systems, and effective airtightness. Over the last few years closer attention has been paid to the performance of these various aspects.

The international seminar on 10 and 11 June 1998 in Brussels will focus mainly on the aspect of airtightness. Airtightness classes for ductwork have been developed by EUROVENT for many years and several countries have airtightness requirements for ducted air distribution systems. But what is the status in practice? What improvements are possible in the future? What is the impact of poor airtightness on system performances: indoor air quality, energy use, etc.? Is it technically possible and useful to increase the requirements? What is the status at CEN level?

It can be seen from the preliminary programme that all key aspects of the issue will be discussed:

- *Ductwork in the overall context of ventilation, IAQ and energy*
- *Overview of standards and regulations*
- *Activities in the context of CEN TC 156 WG3 "Ductwork"*
- *Overview of practices in various countries*
- *Preliminary outcome of the survey among manufacturers and installers*
- *Results of field measurements in the SAVE-DUCT project*
- *Progress in duct design of the last 25 years*
- *Economic aspects of improved airtightness*
- *and more...*

Leading experts in the field have been contacted to give presentations, and more presentations are planned.

Those interested in contributing or receiving more information should contact P. Wouters or A. Bossaer (telephone +32 2 655 77 11, Fax +32 2 653 07 29 or email bossaer@bbri.be)

The initiative for setting up this seminar is taken in the framework of the EC programme SAVE (Specific Actions for Vigorous Energy efficiency measures).

## **Due Out Soon**

### **New Technical Notes from the AIVC**

*Ventilation Technology in Large Non-Domestic Buildings, by  
Don Dickson*

*Energy Impact of Ventilation - Estimates for the Service and  
Residential Building Sectors, by Malcolm Orme*

# AIVC Information Products and Publications

## JOURNALS

**\*Air Infiltration Review.** Quarterly newsletter containing topical and informative articles on air infiltration research and application. Annual subscription £25.00

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

## AIRBASE

The AIVC's bibliographical database, containing over 10,000 records on air infiltration, ventilation and related areas, is available on CD or as a diskette package for your personal computer. AIRBASE £150.00 plus VAT where applicable

## WORLD WIDE WEB

The AIVC's home page holds Air Infiltration Review, publications and conference details and a list of papers based on the current edition of Recent Additions. The address is <http://www.aivc.org/>

## GUIDES

**Guide to Energy Efficient Ventilation,** Liddament M W, 1996 GV £50.00

**Air Infiltration Calculation Techniques: an Applications Guide,** 1986, CT £15.00

**Air infiltration control in housing: Handbook,** 1983 HNBK £15.00

## TECHNICAL NOTES

**Validation and comparison of mathematical models,** 1983 TN 11 £15.00

**Wind pressure data requirements,** 1984, TN 13 £15.00

**Wind Pressure Workshop Proceedings,** 1984, TN 13.1 £15.00

**Leakage Distribution in Buildings,** 1985, TN 16 £15.00

**Ventilation Strategy - A Selected Bibliography,** 1985, TN 17 £15.00

**Airborne moisture transfer: workshop proceedings,** 1987, TN 20 £15.00

**Review and bibliography of ventilation effectiveness,** 1987, TN 21 £15.00

**Inhabitants' behaviour with regard to ventilation,** 1988, TN 23 £15.00

**AIVC Measurement Techniques Workshop,** 1988, TN 24 £15.00

**Minimum ventilation rates,** IEA Annex IX 1989, TN 26 £15.00

**Infiltration and leakage paths in single family houses,** 1990, TN 27 £15.00

**A guide to air change efficiency,** 1990, TN 28 £15.00

**A guide to contaminant removal effectiveness,** 1991,

**A Strategy for Future Ventilation Research and Applications,** Liddament M W, 1992, TN 37 £15.00

**\*A Review of Ventilation Efficiency,** Liddament M W, 1993, TN 39

**\*An Overview of Combined Modelling of Heat \*Transport and Air Movement,** Kendrick J F, .1993, TN 40

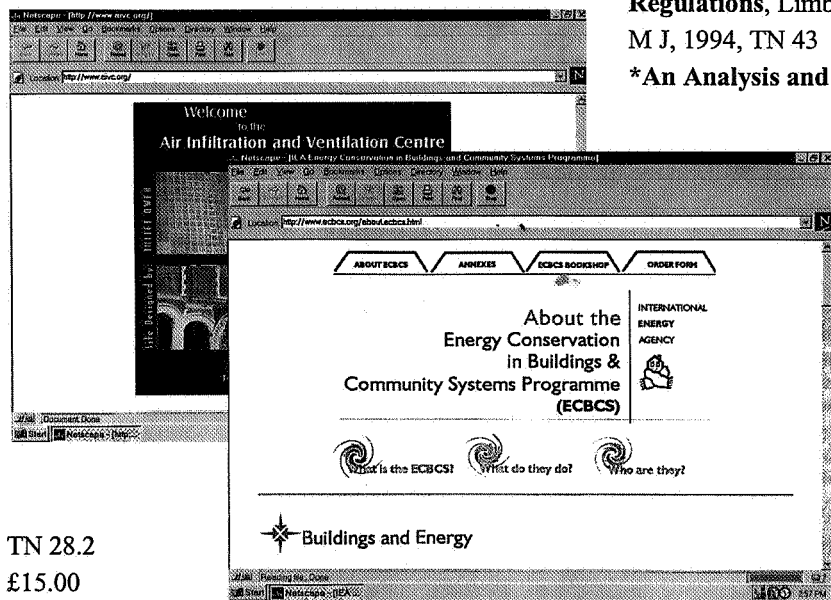
**\*Infiltration Data from the Alberta Home Heating Research Facility,** Wilson D and Walker I, 1993, TN 41

**\*Current Ventilation and Air Conditioning Systems and Strategies,** Limb M J, .1994, TN 42

**\*Ventilation and Building Airtightness: an International Comparison of Standards, Codes of**

**Practice and Regulations,** Limb M J, 1994, TN 43

**\*An Analysis and**



TN 28.2

£15.00

## Reporting

**guidelines for airflows in buildings,** 1991, TN 32 £15.00

**A review of building air flow simulation,** 1991, TN33 £15.00

**Air flow patterns: measurement techniques.',** 1991, TN 34 £15.00

**Advanced ventilation systems,** 1992, TN35 £15.00

**Airgloss Air Infiltration Glossary,** Limb M J, 1992, TN 36 £15.00

**Data Summary of the AIVC's Numerical Database,** Orme M S, 1994, TN 44

**\*Air-to-Air Heat Recovery in Ventilation,** Irving S, 1994, TN45  
**\*1994 Survey of Current Research,** Limb M J, 1995, TN 46

**\*Energy Requirements for Conditioning of Ventilation Air,** Colliver D, 1995, TN 47

**\*The Role of Ventilation in Cooling Non-Domestic Buildings,** Irving S J, 1997, TN 48

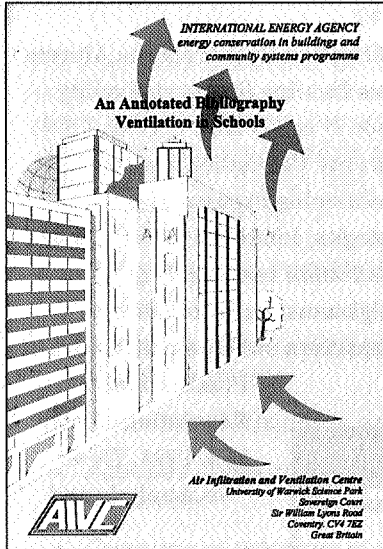
## ANNOTATED BIBLIOGRAPHIES

(Participants only)

**Ventilation and infiltration characteristics of lift shafts and stair wells**, 1993, BIB1 £15.00

**Garage Ventilation**, 1994, BIB2 £15.00

**Natural ventilation**, 1994, BIB3 £15.00



**Air intake positioning to avoid contamination of ventilation air**, 1995, BIB4 £15.00

**Heat pumps for ventilation exhaust air heat recovery**, 1996, BIB5 £15.00

**Ventilation in Schools**, 1997, BIB 6 £15.00

**Ventilation and Acoustics in Buildings**, 1997, BIB 7 £15.00 (available soon)

## IEA ENERGY CONSERVATION IN BUILDINGS BOOKSHOP

**IEA Energy Conservation News**  
Twice yearly newsletter of the IEA Energy Conservation in Buildings Programme  
IEA NEWS Subscription free of charge

**Energy Conservation Bookshop Publications Catalogue**  
A list of over 100 bookshop publications is available free of charge.

## AIVC CONFERENCE PROCEEDINGS

Papers from earlier AIVC Conference Proceedings are also available. Contents pages can be forwarded on request.

**'Ventilation System Performance'** Belgirate, Italy, 1990, CP 11 £35.00  
**'Air Movement and Ventilation Control within Buildings'**, Ottawa, Canada, 1991, 3 volumes, CP 12 £50.00

**'Ventilation for Energy Efficiency and Optimum Indoor Air Quality'**, France, 1992, CP 13 £50.00

**'Energy Impact of Air Infiltration and Ventilation'**, Denmark, 1993, CP 14 £50.00

**'The Role of Ventilation'**, Buxton, UK, 1994, CP 15 £50.00

**'Implementing the Results of Ventilation Research'**, Palm Springs, USA, 1995, CP 16 £50.00

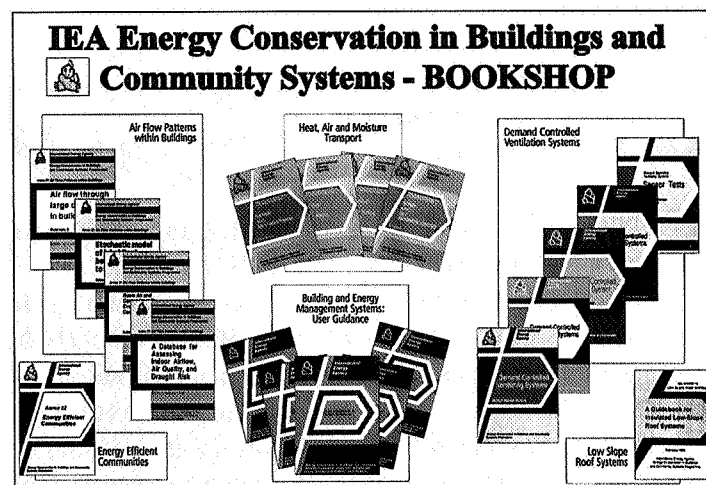
**'Optimum Ventilation and Air Flow Control in Buildings'**, Gothenburg, Sweden, 1996, CP 17 £50.00

**'Ventilation and Cooling'**, Athens, Greece, 1997, CP 18 - Forward orders only

## LITERATURE LISTS

(\*Participants only)

- Pressurisation - infiltration correlation: 1. Models, LL 1
- Pressurisation - infiltration correlation: 2. Measurements, LL 2
- Weatherstripping windows and doors, LL 3
- Caulks and sealants, LL 4
- Domestic air-to-air heat exchangers, LL 5
- Air infiltration in industrial buildings, LL 6
- Air flow through building entrances, LL 7
- Air infiltration in commercial buildings, LL 8
- Air infiltration in public buildings, LL 9
- Carbon dioxide controlled ventilation, LL 10
- Occupancy effects on air infiltration, LL 11
- Windbreaks and shelterbelts, LL 12
- Air infiltration measurement techniques, LL 13
- Roofs and attics, LL 14
- Identification of air leakage paths, LL 15
- Sick buildings, LL 16
- Flow through large openings, LL 17



\*These items are free of charge to enquirers in participating countries - Belgium, Canada, Denmark, Finland, France, Germany, Netherlands, New Zealand, Norway, Sweden, UK and USA



*Please cut out page and fold along lines to return to AIVC*

**Air Infiltration and Ventilation Centre  
Sovereign Court  
University of Warwick Science Park  
Coventry CV4 7EZ  
Great Britain**

# Forthcoming Conferences

## **Healthy Buildings/IAQ '97 Global Issues and Regional Solutions**

September 28-October 2, 1997  
Washington DC, USA

Prof James E Woods, Virginia Polytechnic Institute and State University, 2990 Telestar Court, Falls Church, VA 22042, USA

## **ISBE International Conference Volatile Organic Compounds in the Environment, Risk Assessment and Neurotoxicity**

October 5-7, 1997  
Pavia, Italy

PRAGMA, VOC Conference, Via S. Giovanni in Borgo, 4 - 27100 Pavia, Italy Tel: +39 382 302 859 Fax: +39 382 27 697

Conference Themes:

Experimental and clinical aspects of neurotoxicity and VOCs. Monitoring human exposure. Mechanistic approaches to neurotoxic risk assessment. Specific studies and state of the art reviews are solicited.

## **International Conference on Energy and the Environment: Efficient Utilisation of Energy and Water Resources**

October 12-14, 1997  
Limassol, Cyprus

Dr Savvas Tassou, Department of Mechanical Engineering, Brunel University, Uxbridge, Middlesex UB8 3PH, UK

## **Programme Industry - Energy Generation The Asia-Pacific Initiative for Renewable Energy & Energy Efficiency Conference**

14-16 October 1997

Jakarta Convention Center, Indonesia  
Alternative Development Asia Ltd, 1406 Leader Commercial Buildings, 54-56 Hillwood Road, TST, Kowloon, Hong Kong, Fax +852 2574 1997, email office@adal.com, Tel: +852 2574 9133

## **ESS97 9th European Simulation Symposium & Exhibition Simulation in Industry**

19-23 October 1997

Passau, Germany  
Philippe Geril, The Society for Computer Simulation International, European Simulation Office, University of Ghent, Coupure Links 653, B-9000 Ghent, Belgium Tel: +32 59 800 804 Fax: +32 9 2234941 email philippe.geril@rug.ac.be

## **Workplace Comfort Forum International Conference - Creating the productive workplace**

29-30 October 1997

Westminster Central Hall, London  
Peter Russell, Abacus Communications, FREEPOST SEA1285, Tunbridge Wells, TN1 1BR, UK, Tel: 01892 531830, Fax: 01892 546385  
Themes are: designing for productivity; people, concentration and work; best practice and gaining

a competitive edge; the future for workplace and environmental design.

## **PLEA 1998 Lisbon Passive and Low Energy Architecture 15th International Conference on Passive and Low Energy Architecture Environmentally Friendly Cities**

1-3 June 1998

Lisbon, Portugal

Conference Secretariat, Portuguese Solar Energy Society/SPEC-RN, Apartado 4076, 4004 Porto Codex, Portugal Tel: +351 2 2007455 Fax: +351 2 312476 email ebm@fe.up.pt

## **CIB World Building Congress 1998 Construction and the Environment**

7-12 June 1998

Gavle, Sweden

Executive Secretariat CIB 1998, Division of Materials Technology, Centre of Built Environment, Royal Institute of Technology, PO Box 88, S-801 02 Gavle, Sweden, Fax: +46 26 14 78 01, Home Page

<http://www.bmg.kth.se/cib98.htm>

## **Roomvent '98 6th International Conference on Air Distribution in Rooms**

June 15-17, 1998

KTH, Stockholm, Sweden

Conference Secretariat, Roomvent '98, KTH, Building Services Engineering, Birnellvagen 34, S-100 44 Stockholm, Sweden Fax: +46 8 411 84 32 email roomvent98@ce.kth.se

## **World Renewable Energy Congress V Renewable energy climate change and the environment**

20-25 September 1998

Florence, Italy

Prof A A M Sayigh, World Renewable Energy Network, 147 Hilmanton, Lower Earley, Reading RG6 4 HN, UK, Tel: +44 0118 961 1364, Fax: +44 0118 961 1365

Topics: solar and low energy architecture; photovoltaic technologies; solar thermal applications; wind energy generation; biomass conversion; energy resources; wave and tidal energy; hydrogen and storage; economics and financing; institutional issues; geothermal and ocean thermal; climatic and environmental issues; renewable energy: manufacturing.

## **GBC '98 Green Building Challenge '98**

26-28 October 1998

Hyatt Regency Hotel, Vancouver, Canada  
Darinka Tolot, GBC '98 Conference Secretariat, CANMET Energy Technology Centre, NRCAN 13/F, 580 Booth Street, Ottawa ON K1A 0E4, Canada, Fax: 613 996 9909, email darinka.tolot@nrcan.gc.ca

# Representatives and Nominated Organisations

## Belgium

\*P. Wouters, Belgian Building Research Institute (WTCB/CSTC), rue de la Violette, 21-23, 1000 Brussels, Belgium. Tel: +32 2-655-7711 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, email: olj@sbi.dk

P.F. Collet, Technological Institute, Byggeteknik, Post Box 141, Gregersensvej, DK 2639 Tastrup, Denmark. Tel: +45 4350 4159 Fax: +45-4350 4069

## Finland

\*J. Sateri, Group Manager, VTT Building Technology, Indoor Climate, PO Box 1804, FIN-02044 VTT (Espoo), Finland Tel: +358 9 4564710, Fax: +358 9 455 2408, email: jorma.sateri@vtt.fi

FISIAQ, Finnish Society of Indoor Air Quality and Climate, PO Box 87, FIN-02151 Espoo, Finland, Tel: +358 9 451 3606, Fax: +358 9 451 3611, email siy@hut.fi

## France

\*Marie-Claude Lemaire, ADEME - Departement Batiment et Collectivites, 500 Route des Lucioles, Sophia Antipolis, F-06560 Valbonne, France Tel: +33 4 93 95 79 56 Fax: +33 4 93 65 31 96, email lemaire@ademe.fr

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. Gehrman, Projektträger BEO - Biologie, Energie, Ökologie, KFA Jülich, Postfach 19 13, 52425 Jülich, Germany Tel: +49 2461 614852, Fax: +49 2461 613131

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 15 260 8427 (Direct: +31 15 2608472 ) Fax: +31 15 260 8432, email: w.degids@bouw.tno.nl

## 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: +47-22-965725, e-mail jom.brunsell@byggforsk.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, Slaghuset, S-21120 Malmö, 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

## UK

\*MDAES Perera, Environmental Systems Division, Building Research Establishment, Garston, Watford, WD2 7JR, UK Tel: +44(0)1923 664486, Fax: +44(0)1923 664796, e-mail pererae@bre.co.uk

M W Liddament (Operating Agent), Oscar Faber Group UK Ltd, Marlborough House, Upper Marlborough Road, St. Albans, Herts, AL1 3UT, Great Britain. Tel: +44(0)181-7845784, 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 5433, email andrew.persily@nist.gov

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



Head of Centre Martin W Liddament, BA, PhD.

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

ISSN 0143 6643  
Tel: +44(0)1203 692050  
Fax: +44(0)1203 416306  
email: airvent@AIVC.org  
http://www.aivc.org/

Operating agent for IEA is Oscar Faber Group Ltd