Air Infiltration Review

a quarterly newsletter from the IEA Air Infiltration and Ventilation Centre

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European NatVent Project Nearing Completion

Martin W. Liddament, Expert Adjudicator for NatVent

The European Joule Programme natural ventilation project, 'NatVent' is rapidly approaching completion with many of the tasks having been completed and now in the process of being prepared for publication and implementation.

The key tasks which have been undertaken include:

Work Package 1 Perceived Barriers to Natural Ventilation

Surveys of architects, consulting engineers , developers, owners and other key groups have been undertaken in each of the eight participating countries to determine the various concerns about implementing natural ventilation. Conclusions are currently being collated but key areas of interest include the need for more knowledge about specialist designs, working examples and reliable calculation techniques. All these issues have been addressed by NatVent.

Work Package 2: Building Monitoring and Performance

A total of eighteen buildings that incorporate natural ventilation have been selected as case studies. They have undergone extensive monitoring of ventilation rates and key indoor air parameters. Over selected periods, occupants have kept diaries of their own level of comfort. Interest has focused on the need to achieve good indoor air quality throughout the year combined with features necessary to secure cooling in the summer. Natural ventilation design, therefore, goes beyond the provision of air flow strategies and includes the application of such elements as thermal mass, solar shading, natural daylighting and control strategies.

Performance criteria and cost are important parameters when choosing between natural ventilation and alternative solutions. Ultimately it is recognised that it is important to demonstrate the viability of natural ventilation in both performance and competitiveness if it is going to succeed in the market place. An advantage of the case study analysis has been the opportunity to highlight the diverse range of solutions and to identify benefits and potential short comings. In some instances, for example, users have experienced difficulty in operating or understanding controls. Mostly these are problems that can easily be rectified but it is important that these experiences should be disseminated to designers to avoid any future problem.

In this issue

Work Package 3 Components and Controls

Several products have been developed as part of NatVent to extend the performance of natural ventilation. These have included:

WP 3.1 Low Pressure Drop Acoustic and Filtration Air Inlets

The focus of NatVent has been the application of natural ventilation in non-domestic buildings situated in urban environments. There has been much interest, therefore, in developing techniques which minimise the adverse effects of outside noise or localised poor outdoor air quality. One task has been to develop guidelines for the location of air inlets (Ajiboye, 1997) and to develop air inlet designs which are capable of damping noise and filtering particles. Designs are currently being tested.

WP 3.2 Constant Flow Air Inlets

A major problem with natural ventilation is the variability in the driving forces of wind and temperature. To ensure a constant flow rate, especially during the winter, when high driving forces could result in excessive heat loss, quite complex control strategies are often needed. As an alternative, 'passive' vents have been developed which provide a measure of pressure independent flow without the need for mechanically controlled actuators. The key has been the development of vents that operate at the extremely low driving pressures of natural ventilation (in some cases of only a few Pascals). An example developed by TNO in the Netherlands is illustrated (DeGids 1997). To demonstrate their viability, an easy to use algorithm has been developed which gives a visual indication of ventilation, air quality and thermal parameters for many ventilation and weather configurations.

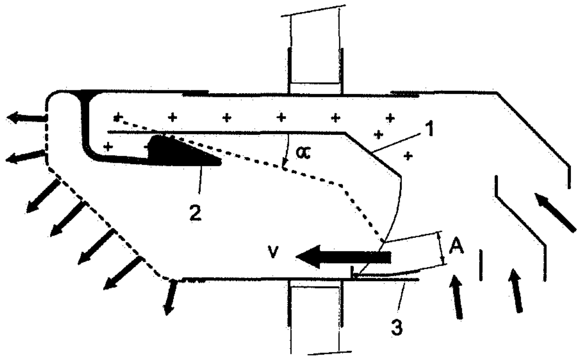

Figure 1: Cross section of a passive pressure controlled inlet COMPRI IAQ.

WP 3.3 Heat Recovery

The incorporation of heat recovery into natural ventilation has been investigated by the Norwegian Building Research Institute. Clearly this approach demands very low pressure drops. The study has included determining the distribution of available driving pressure at key locations within each participating country. A working example of heat recovery has been developed (Figure 2) and is currently undergoing evaluation. Current designs incorporate a small 'rising' fan to assist air flow through the system. A typical system is illustrated. The fan is extremely energy efficient and consumes approximately 0.25W for each l/s of air flow. Further details are given by Skaret et al 1997)

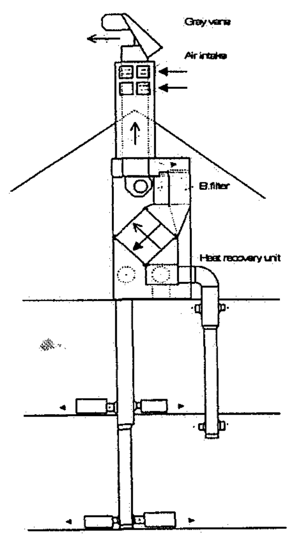

Figure 2: A practical simple unit for a dwelling for natural ventilation with heat recovery using an air to air heat exchanger.

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.

WP 3.4 Low Energy Cooling

An important aspect of natural ventilation design is to avoid the need for refrigerative cooling. In much of Northern Europe, over which NatVent is directed, excessive outdoor temperature and humidity rarely present a problem. Instead, buildings tend to overheat as a consequence of high internal heat loads and solar gains. The task, therefore, is to develop designs that minimise these problems. Hardware and controls for cooling are being developed and evaluated at Delft University of Technology in the Netherlands (Liam and Paassen 1997). Design is aimed at reducing the peak day time temperature yet avoiding an uncomfortably cool indoor temperature at the start of the day. Control strategy for night cooling has focused on:

- predictive control;
- cooling day control;
- set-point control;
- slab temperature control;
- degree hours control.

To maximise the benefit of night cooling it has been shown that areas of glazing should be restricted to 40% of the envelope area and that external shading should be applied. Internal heat gains should be limited to no more than $25W/m^2$. Optimum night air-change ventilation rates for cooling are estimated at 6 air changes/hour.

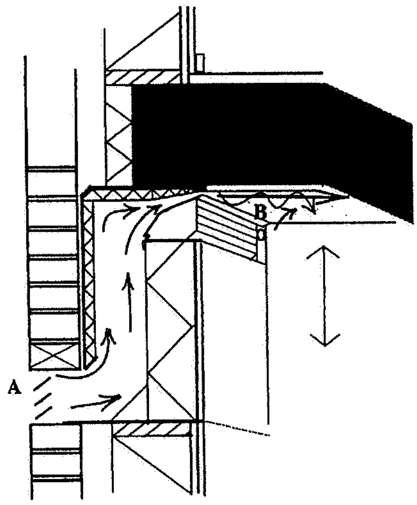

Figure 3: Integrated trickle vents in the facade with a noise reduction canal.

WP3.5 Integration and Maintenance

Integration and maintenance has been concerned with developing all the elements of NatVent into a simple (but reliable) design tool (Svensson and Aggerholm 1997). Key elements are:

- driving forces (wind and temperature);
- air flow through components;
- solar radiation;
- thermal model.

These components have been incorporated into a visual basic model with a simple user interface. Behind this is an extensive numerical database and pre-selected default data. Output includes air change rate, heat losses and related data. This model is currently undergoing thorough testing.

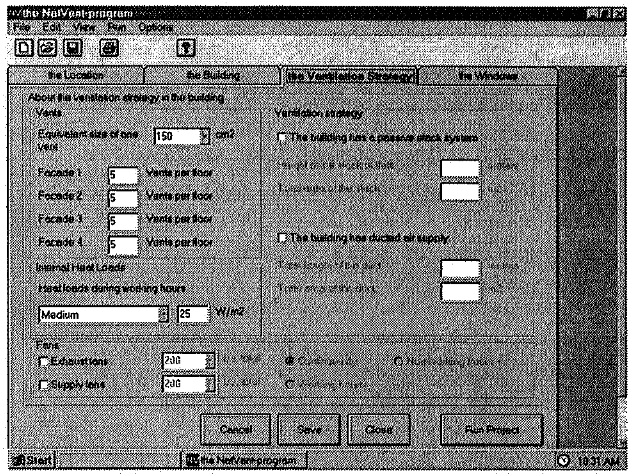

Figure 4: Screen display from NatVent package

Exploitation and Products

NatVent has undertaken one of the most extensive evaluations of natural ventilation. By analysing existing buildings and needs it has been possible to develop new ideas into market ready products. The planned product range includes:

- **Tool-Kit CD-ROM:** Already available in test form, this CD will contain all the software and reporting products of NatVent. Contents include full information about the case study buildings, information about the products and partners and the design software products. Future maintenance and technical support services are also planned.

- **Guidebook:** A basic guidebook is being prepared that describes the work of NatVent and its outcome. This is aimed at practitioners, decision makers and owners. It is essentially non-technical with the results being presented visually.

- **Products:** Products to be developed by consortium members include:

- *acoustic, filtrating and constant flow air intakes;*
- *low pressure heat recovery systems;*
- *night cooling devices and controls.*

The NatVent project is scheduled to be completed in June of this year. The consortium partners are: UK Building Research Establishment, Environmental Engineering Division; Belgian Building Research Institute, Division of Building Physics and Indoor Climate; Danish Building Research Institute, Energy and Indoor Climate; TNO Building and Construction Research, Department Indoor Environment; J&W Consulting Engineers AB, Division of Building Physics and Indoor Environment; Willan Building Services; Sulzer Infra Lab; Delft University of Technology, Laboratory of Ref Eng and Indoor Climate Tech; Norwegian Building Research Institute.

References

Ajiboye P, Hesketh M, Willan P, "The significance of urban pollution in relation to ventilation air supply", CIBSE National Conference, 1997, volume 2, pp 215-224.

De Gids W F, "Controlled air flow inlets", UK, AIVC, 18th AIVC Conference, 1997, pp 245-255.

Skaret E, Blom P, Brunsell J, "Energy recovery possibilities in natural ventilation of office buildings", UK, AIVC, 18th AIVC Conference, 1997, pp 311-321.

Liem S H, van Paassen A H C, "Hardware and controls for natural ventilation cooling", UK, AIVC, 18th AIVC Conference, 1997, pp 60-68.

Svensson C, Aggerholm S, "A design tool for natural ventilation", UK AIVC, 18th AIVC Conference, 1997, pp 163-174.

SECOND ANNOUNCEMENT

19th AIVC Annual Conference

To be Held in Oslo, Norway, 28-30 September, 1998

Theme: "Ventilation Technologies In Urban Areas"

Urban Areas present particular problems to ventilation design and implementation *(e.g. poor air quality; excessive noise and heat island effects)*. The purpose of this conference is to clarify the solutions needed to overcome these difficulties. The programme will include full sessions and poster displays (preceded by 5 minute oral presentations) and both research and case study papers are welcome on the following, or related, topics:

- *Outdoor air pollutant characteristics;*
- *Air intake location;*
- *Air quality control strategies*
- *Cooling technologies*
- *Acoustic control*
- *Filtration*
- *Solution for offices, retail stores*
- *Solution for light industrial building*
- *Solution for Dwellings*
- *Case Studies*

Conference Venue and Fees

The venue for the conference will be the Holmenkollen Park Hotel Rica which is well situated approximately 15 minutes from the centre of Oslo and Fornebu International Airport. The conference will be held over 3 full days and the overall cost *(inclusive of 3 nights bed/breakfast, 3 lunches, conference attendance, proceedings and Gala dinner)* will be 650 pounds sterling for delegates from AIVC member countries* and 675 pounds sterling for delegates from non-AIVC member countries. There is also a generous early payment discount for registrations received before 31st July 1998.

For further information please contact the Conference Secretariat:

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Coventry, CV4 7EZ, UK
Tel: +44 (0)1203 692050, Fax: +44 (0)1203 416306, e-mail: airvent@aivc.org
Also, visit our WWW Home Page for more information on AIVC activities http://www.aivc.org/
AIVC Member countries are: Belgium, Canada, Denmark, Finland, France, Germany, Greece, Netherlands, New Zealand, Norway, Sweden, UK and USA

International Energy Agency Energy Conservation in Buildings and Community Systems Programme - Annex 35

HYBVENT – Hybrid Ventilation in New and Retrofitted Office Buildings

by Per Heiselberg, Aalborg University, Aalborg, Denmark

Paper presented at the BCS-SHC Joint Meeting held at Port Douglas, November 3-4, 1997

Background

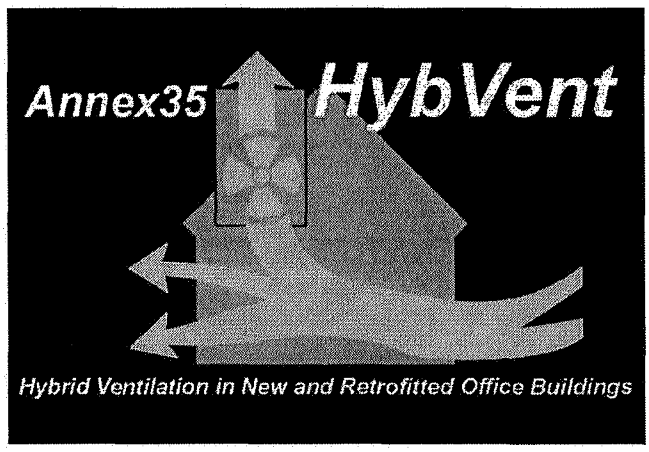
Soon after the energy crisis in 1973 everybody focused their attention on thermal insulation, airtightness of buildings and heat recovery to decrease energy consumption for heating (and cooling) of buildings. Buildings were designed to be isolated from the outdoor environment with an indoor environment controlled by artificial lighting, mechanical ventilation and heating and cooling systems.

Today, in the design of new buildings and retrofit of old buildings, the attention has been turned towards a more integral energy design with focus not only on thermal insulation, airtightness and heat recovery but also on optimal use of sustainable technologies such as passive solar gains, daylight and natural ventilation. The buildings are designed in an interplay with the outdoor environment and are utilising it to create an acceptable indoor environment whenever it is beneficial.

The extent to which sustainable technologies can be utilised depends on outdoor climate, building use and building location and design. Under optimum conditions sustainable technologies will be able to fulfil the demands for heat, lighting and fresh air, while in some cases supplementary mechanical systems will be needed and in other cases it will not be possible to use sustainable technologies at all.

In well thermally insulated office buildings, which are more and more frequent in IEA countries, ventilation (and cooling) account for more than 50% of the energy requirement, and a well-controlled and energy-efficient ventilation system is a prerequisite to low energy consumption. Natural ventilation and passive cooling are sustainable, energy-efficient and clean technologies as far as they can be controlled, (that is if well modelled and understood). They are well accepted by occupants and should therefore be encouraged wherever possible.

Unfortunately, the design of energy efficient ventilation systems in office buildings is often turned into a question of using either natural ventilation and passive cooling or mechanical ventilation and cooling.



Annex 35 HybVent.

This prevents a widespread use of sustainable technologies because a certain performance cannot be guaranteed under all conditions. In fact in the large majority of the cases a combination of systems - hybrid ventilation - would be beneficial depending on outdoor climate, building design, building use, and the main purpose of the ventilation system.

The number of office buildings to be retrofitted in most IEA countries is now much larger than the potential for new buildings. In many cases there is a large potential for use of sustainable technologies either as a supplement to the existing mechanical systems or as the main part of solutions in cases where classic ventilation systems are impossible to install in an existing building. Innovative hybrid ventilation systems should be developed or improved for that purpose.

Hybrid Ventilation

Hybrid ventilation systems can be described as systems providing a comfortable internal environment using both natural ventilation and mechanical systems, but using different features of the systems at different times of the day or season of the year. It is a ventilation system where mechanical and natural forces are combined in a two mode system. The basic philosophy is to maintain a satisfactory internal environment by alternating between these two modes to avoid the cost, energy penalty and consequential environmental effects of full year round air conditioning. The operating mode changes with the seasons, and within individual days, such that at any point in time the current mode reflects the external environment and takes maximum advantage of ambient conditions.

Hybrid ventilation should depend on building design, internal loads, natural driving forces, outdoor conditions and season and should fulfil the immediate demands to the indoor environment in the most energy efficient manner. The control strategies for hybrid ventilation systems in office buildings should maximise the use of ambient energy with an effective balance between the use of advanced automatic control of passive devices and the opportunity for users of the building to exercise direct control of their environment. The control strategies should also establish the desired air flow rates and air flow patterns at the lowest energy consumption possible.

Objectives

The Annex 35 research project is aiming at a better knowledge of hybrid systems and focusing on development of control strategies and performance prediction methods for hybrid ventilation in new and retrofitted office buildings. Its main objectives are:

- to develop control strategies for hybrid ventilation systems in new and retrofitted office and educational buildings
- to develop methods to predict ventilation performance in hybrid ventilated buildings
- to select suitable measurement techniques for diagnostic purposes to be used in buildings with hybrid ventilation systems
- to promote energy and cost effective hybrid ventilation systems in office and educational buildings

Strategy and Approach

To fulfil the objectives the work is divided into the following tasks:

A State of the art review of hybrid ventilation, control strategies and algorithms

B Development of control strategies for hybrid ventilation in new and retrofitted office buildings

C Development of decision tool for hybrid ventilation applications

D Implementation and demonstration of hybrid ventilation

E Reporting

"State of the Art" Review

A state of the art review of the potential and usefulness of hybrid ventilation systems will be carried out. The review will among other things focus on the impact of differences in climate (including seasonal differences such as winter heating and summer cooling), building design, building use and internal loads on energy performance, indoor air quality and comfort. The review will provide examples of existing systems and show solutions to specific problems (fresh air supply, excess heat removal, etc.) in a particular building located in a certain outdoor climate.

The review will include a study of the existing office building stock in each participating country and will classify it according to its potential for hybrid ventilation. In this way the viability of hybrid ventilation systems in both new and retrofitted buildings can be demonstrated.

A market survey will be carried out on commercially available ventilation components. In addition, a review of control strategies and algorithms being used in hybrid ventilated buildings will be carried out together with a critical view of their integration in the building energy management system (BEMS). A parametric analysis will be carried out to examine the effects of local versus building driven control of the various ventilation components.

Development of control strategies

Integration of sustainable ventilation technologies and classic mechanical systems in a common hybrid ventilation system requires development of new control strategies. By these strategies the hybrid ventilation system should at any time and for a certain combination of internal loads, outdoor conditions and comfort requirements be able to fulfil the immediate demands to the indoor environment in the most energy efficient manner. The demands to the indoor environment also include the ability of the hybrid ventilation system to create optimum air flows and air flow patterns in the building.

Different control strategies will be developed dependent on climate and main purpose of the ventilation system (indoor air quality, thermal conditioning). The focus of development will be on the problem of switching between natural and mechanical modes and how to establish an effective balance between the use of advanced automatic control and the possibility for users to exercise direct control of their environment.

The cost effectiveness of different ventilation and control strategies will be investigated by comparing capital and operational costs against a typical refurbishment or new build in each participating country.

Theoretical and experimental studies

A better understanding and a better control of the natural ventilation process is a prerequisite for successful hybrid ventilation and can be obtained by theoretical and experimental studies that must go hand in hand.

There do not exist any directly applicable models for analysis of hybrid ventilation. Such analysis models require an integration of models for air flows and thermal simulation. This will be achieved in the annex by combining existing models and developing the necessary additional modules.

Another possibility is to use a probabilistic approach in the development of analysis models. Such models should be able to predict statistical occurrences of heat and air flow rates as well as contaminant removal efficiency and are models in which data are input together with their uncertainties, and whose output is frequency distributions. The statistical model will be developed by combining physical models of the phenomena involved (air, heat and contaminant transfer, occupant behaviour, meteorological data, interaction between wind, environment and building, etc.) with stochastic models.

In the case of hybrid ventilation it is necessary to take a range of new considerations into account in the analysis. Some of these are: translation of meteorological data from weather stations into urban data, occupant behaviour and perception, pressure distribution on buildings and time-dependent ventilation capacity.

Development of decision tool

In the implementation of hybrid ventilation in office buildings the very first stages of the design process are very important, because a lot of the decisions taken here are very important for the success of hybrid ventilation.

Architects therefore need tools to help them estimate the critical parameters for application of hybrid ventilation, evaluate if hybrid ventilation can be an option and to make the right choices if it is.

Development of a decision tool for hybrid ventilation will be based on theoretical analysis, laboratory experiments and pilot studies.

Implementation and demonstration of hybrid ventilation

Hybrid ventilation is a relatively new concept and an effective way to promote the use of this concept is to implement and demonstrate it in real office buildings.

Therefore, pilot studies will be monitored to collect data on the performance (indoor air quality, thermal comfort, energy consumption, etc.) and environmental impact of hybrid ventilation systems and to evaluate corresponding control strategies. Pilot studies will include both retrofitted and new-built designs in all participating countries to highlight similarities and differences in climatic (including seasonal differences), institutional and cultural (developers and occupants), and technology transfer issues. The pilot studies will concentrate on success stories of hybrid ventilation but will also critically highlight problematic cases and can be a powerful tool to demonstrate to both legislators, developers, brief specifiers and occupants the relative merits of the applicability of hybrid ventilation.

Valuable measurement methods in mechanical ventilation diagnostics are not automatically applicable for natural ventilation systems. Suitable measurement techniques will be selected and refined for these experiments.

Reporting

The state of the art review will be summarised in a report, first in an internal report for use by annex participants and later in a public version. Three additional reports summarising results of the individual tasks will be made.

The report "Principles of hybrid ventilation " will be drafted on the basis of experience gained as well as from previous research (state of the art), from theoretical and experimental studies mentioned above, and from the monitored pilot studies. It will be written for architects and engineers. Therefore, architects should be in the editorial team.

Expected results

The expected results of the annex are:

- "Principles of Hybrid Ventilation", including solutions for efficient, energy and cost-effective hybrid ventilation systems. Recommendations on control strategies
- Analysis tools for predicting the performance of hybrid ventilation. Decision tool for application of hybrid ventilation
- Refinement and recommendations of suitable measurement techniques for diagnostics and commissioning of hybrid ventilation systems.
- Demonstration of principles through pilot studies

Annex Beneficiaries

The target audience for "Principles of Hybrid Ventilation" will be both architects and engineers, while the decision tool will be targeted towards architects only.

The reports and developed analysis tools will be available for engineering offices, helping them to provide advice to architects and to design systems.

Annex Organisational Structure and Programme Plan

The annex is divided into five tasks with a task leader each except for the reporting task. The operating agent and the four task leaders form the Annex Management Group. In the reporting task different editorial groups will be formed for the different reports.

All countries are required to participate in Task A and in minimum one additional Task of B through D. The minimum level of commitment is to be decided at a later meeting.

The three year working phase will begin on August 1st, 1998 and end on July 31st, 2001. The reporting phase is scheduled to last one year after the working phase and end on July 31st, 2002. In this way it is possible to include all results in the reports. At the workshop there was a great concern about the time schedule for pilot studies. In the case of new build or refurbished buildings planning, construction and a one year measuring period requires tight correspondence between annex and pilot study time schedules that can be difficult to achieve. Any decisions regarding this are postponed until specific pilot studies are available for the annex.

Future Actions

Before the next meeting the OA will make a draft of the annex text (project definition) and a small editorial group will review it. The final draft will be discussed at the next meeting.

As the time schedules for pilot studies are very tight, it is important to search for suitable projects or buildings and as soon as possible have some available for the annex.

Next Meetings

Kick off meeting

Location and time: Italy, March 25-27, 1998

Host: ENEA, Energy Saving Department ERG SIRE, Roma, Mr Marco Citterio

Objectives:

- Information on Annex 35 for all interested persons; observers welcome
- Presentation of draft of Annex text
- Information on available Pilot Studies
- Nomination of Task Leaders
- Confirmation of Preparation Phase participation

First Expert Meeting

Location and time: Oslo, Norway, October 2-4, 1998 (After AIVC Conference)

Host: NUST, Norwegian University of Science and Technology, Trondheim, Dr Per Olaf Tjelflaat.

AIVC Ventilation Research Update '98

An invitation to contribute to the AIVC's triennial survey of current research into air infiltration, ventilation and related indoor environmental problems in buildings

Reminder

The closing date for submissions has been extended to Friday 24th April 1998

Invitation to Register Your Research Activities

The current survey form will take only a few moments to complete.

Publication in Database Format

The final publication will be available in 1998, containing the entire list of replies, fully indexed, in terms of research topic, author and country of origin. It will be published in both hard copy and database format, and run alongside our bibliographic database, AIRBASE.

Deadline

To contribute your project, please complete the Survey Form (located on the Web), or send your own word processed version on diskette to the AIVC, via surface mail, fax or email ***(survey@aivc.org).*** The Web online survey form can be found on **http://www.aivc.org/survey.html.** All researchers who contribute will receive a complimentary database version of the whole survey.

All replies must be received by Friday 24th April 1998.

ASHRAE - Particles in Buildings

A report on the winter ASHRAE Meeting
held San Francisco 16th - 21st January 1998
by Martin W. Liddament, Head, Air Infiltration and Ventilation Centre

There is considerable evidence indicating that airborne particles can contribute to poor health. While standards for ambient outdoor concentrations have been formulated in many countries, the situation concerning indoor concentrations is still not well understood. As part of a continuing review of this issue, an update of current developments was presented in a seminar at the winter ASHRAE meeting.

Properties of Particles

Susanne Hering of Aerosol Dynamics, Berkeley California, began by summarising the characteristics of outdoor (ambient) particulate matter and the characteristics of particles in general. Typically there are between 1000 - 2000 particles in each cubic centimetre of outdoor air, while the mass of particles in each cubic metre of air can vary between 2 - 200 μg. Particle sizes range between .0005 - 50 μm. The chemical nature of particles is varied and include sulphates, nitrates, carbon products, aromatics, hydrocarbons and many other substances. Concentrations, especially in or close to urban environments tend to show a distinct diurnal variation in response to traffic emissions and working activities. Essentially, atmospheric particles are grouped into two distinct size ranges i.e. a 'fine' particle band (approximately 0.1 - 1 μm) and coarse particles (5 - 50 μm). Each range has its own set of chemical properties while individual particle types have their own characteristic shape and properties. Some particles are volatile and can be found in both the vapour and solid phase. Their actual state depends on conditions such as ambient temperature, relative humidity and vapour concentration. The nature of particles, therefore, is extremely complex, thus making them very difficult to characterise.

The author continued by describing her work on sampling particles both inside and outside dwellings. A total of 24 air conditioned and non air conditioned dwellings were sampled on the basis of a two week average concentration. The purpose was to identify the proportion of outdoor particulate matter that entered each home and to identify general indoor concentrations. Simple filtration samplers (see Figure 1) were used through which air was continuously passed at 0.4 l/min. In each case, three samplers were placed inside the dwelling and three outside. Measurements included total mass, nitrates, sulphates and nitric acid. Since sulphates are not usually generated indoors, the sulphate measure was regarded as a good 'tracer' for the penetration of outdoor particles of size up to 2.5 μm ($pm_{2.5}$) into a space. The general conclusions of the study were that:

- Sulphate ratios between indoor and outdoor concentrations varied between 60 - 100% with the higher levels occurring in the non-air conditioned homes. Higher values were thought to be due to window opening.
- nitrate concentrations did not follow the pattern of sulphates and varied between 0.1 to 1.8 of the outdoor value. Much of this variability was associated with ammonium nitrate which was influenced by many chemical and thermal effects. Also nitrates occur from indoor sources.
- non nitrate mass penetration into the home accounted for between 40 -100% of the $pm_{2.5}$ particles found indoors.

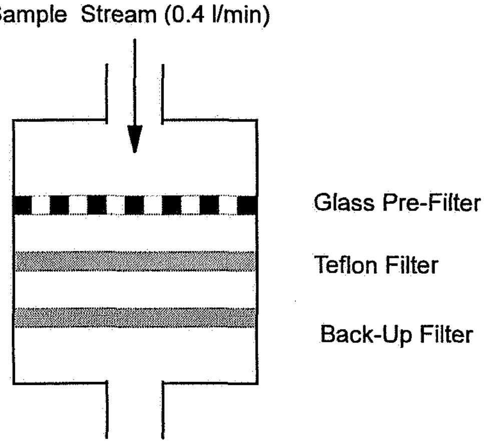


Figure 1: Simple sampling system used to measure particle concentration

Eliminating Sickness by Particle Control

Richard Fogerty of New Trend Environmental, Canada, described work on reducing IAQ problems by tracking and isolating particle sources. He cited various examples where ill health correlated with the presence of 'ultra fine' particles in the 0.1 - 1.0 μm range. Often it was found that regions of a building in which high levels of sickness and absences were reported correlated with the presence of such particles, whereas conventional CO_2, CO and NO_x monitoring indicated no problem. Some of the problems encountered and identified by particle monitoring included:

- entrainment of exhaust;
- leaking furnace contaminating a school;
- emissions from a poorly maintained photocopier;
- cigarette smoke from a food hall penetrating the offices above;
- penetration of particles into offices from a refinery;

- office contamination from a ferry port due to entrainment by a poorly located air intake;
- laundry dust in a hospital;
- vehicle exhaust.

In all cases, sickness problems had been cured once the source of the problem had been identified and eliminated.

Biological Particles

The biological properties of contaminants were considered by Tina Reponen from the University of Cincinnati. Bio particles include:

- fungal spores;
- bacteria;
- actinomycetes.

Each of these contaminants is capable of inducing respiratory or toxic reactions while bacteria can also induce infections. Actinomycete is bacteriological but can look like fungi. Health effects are similar to fungi and tend to be found in buildings suffering from mould problems.

Collection of biological particles is difficult because it is necessary to both collect them and yet ensure that they don't undergo biological change during sampling and analysis. As a result, the physical (quantity) and biological characteristics usually have to be measured separately. Various sampling devices were outlined which have been developed to improve sampling and analysis accuracy.

Development of Standards

Steven Turner of the Chelsea Group, Florida, reviewed world-wide standards covering particles. He suggested that aspects that should be considered in the development of future standards should include:

- concentration in the outside (ambient) air;
- properties of the outdoor air intake;
- indoor air concentrations;
- levels of concern in relation to indoor air quality;
- emerging issues.

Currently there are many standards and guidelines covering the outdoor air but little in relation to the indoor air. Emerging issues included:

- measurement issues: outdoor techniques are not necessarily acceptable for indoor measurement.
- coarse vs fine mode particles: these should be considered separately.
- filtration requirements: this should cover the use of recirculated air in place of outdoor air, filtration performance in relation to particle size, and pressure drop limits.

Various standards and guidelines were outlined covering particles. These included:

Maintenance and Sanitation in Buildings (Japan): This was cited as one of the oldest laws covering indoor particulate matter, dating back to 1970. It sets a limit on suspended particles of size up to 10μm (pm_{10}) of 15 $\mu g/m^3$ at any time. Measurement techniques are also covered by this regulation.

ASHRAE Std 62-1989: This covers the acceptable quality of outdoor air for pm_{10}, averaged at 150 $\mu g/m^3$ over a 24 hour weighted average and 50μg average over 1 year. No limit is specified for the indoor value.

Finnish Society for IAQ and Scanvac (Scandinavia): Three indoor air quality classes are specified in relation to total suspended particles (TSP). These are:

- Class AQ1: 0.06$\mu g/m^3$ (maximum TSP)
- Class AQ2: 0.015 $\mu g/m^3$
- Class AQ3: limit set by designer and occupier.

Australian Draft Standard: This is in the process of development but both a prescriptive engineering procedure and a performance based approach are being considered for dealing with particle concentrations.

USA Environmental Protection Agency: The EPA has guidelines for the maximum acceptable outdoor concentrations of pm_{10}s set at :

- 150 $\mu g/m^3$ (24 hour average)
- 50 μg (1 year average)

Currently proposed levels for $pm_{2.5}$'s are at:

- 0.65 $\mu g/m^3$ (24 hour average)
- 0.15 $\mu g/m^3$ (1 year average)

World Health Organisation (Europe): a standard for total suspended particles of 260 $\mu g/m^3$ has been set but guidelines are currently being reviewed.

Proposed European Directive for pm10's: a proposed EC directive for maximum outdoor pm_{10} concentrations has suggested:

- 50 $\mu g/m^3$ (24 hour average)
- 30 $\mu g/m^3$ (annual average)

Forum - Microbiological Sampling

This was an informal forum, focused on microbiological sampling in buildings. In introducing this topic, the feeling was expressed that criteria for sampling had been established but guidelines were diverse and poorly disseminated. Recent developments have looked at bio-aerosols, their growth and their effect on human health. Issues cover sampling techniques and methods to relate illness symptoms to specific causes and difficulties associated with sampling errors. At present there is no clear consensus on how and when microbiological sampling should be undertaken or under what conditions. There is also a lack of knowledge about links between illness and types of contaminants and concentrations. ASHRAE Technical Committee 2.03 on gaseous air contaminants is reviewing the needs of biological sampling.

Forum - ASHRAE Standard 52.2 Method of Testing General Ventilation Air Cleaning Devices

Continuing with particulate contaminant removal, a forum was held to review progress of ASHRAE Standard 52.2. This is currently out for public review.

- This revised standard has established a new method to test the efficiency of filters in removing particles in the size range 0.3 μm to 10 μm. This is aimed at covering:
- initial efficiency (i.e. as a new filter);
- particle size deposition;
- pressure drop;
- efficiency change with dust loading;
- minimum efficiency;
- relevance to indoor air quality applications.

Key characteristics cover

- precise efficiency vs. particle size
- performance after several cycles of dust loading;
- pressure drop (initial)
- pressure drop after final dust loading cycle;
- dust holding capacity.

The draft standard is now out for public review.

Symposium on Advanced Turbulence Models for Room Air Flow Prediction

This symposium was devoted to looking at developments in room airflow simulation.

A Summary of Turbulence Models

Peter Nielsen began this symposium by outlining the range of turbulence models available for room air flow prediction. He stressed that the representation of turbulence was only one aspect of computational fluid dynamics modelling and that it was also important to ensure that the boundary conditions and system equations were also accurately formulated. A main problem is that room air flow often borders between the turbulent and transitional (laminar to turbulent) regimes. Also flow is influenced by both momentum and buoyancy forces, either of which may dominate. It was therefore important to select the appropriate turbulence model according to conditions. Each model was described and it was concluded that turbulence models should be selected according to the following guidelines:

- initial iterations - zero equation model;
- all round predictions - k-ε model;
- stratified (low velocity) flow - k-ε with damping;
- boundary layer flow - Low Reynolds Number model;
- Transitional Flow - large eddy simulation.

Large Eddy Simulation

The topic of large eddy simulation (LES) was discussed in more detail by Steve Emmerich of NIST in Washington. He emphasised that, in general, it was difficult to simulate room airflow because much was happening. LES is an approach in which the characteristics of turbulent eddies are directly incorporated into the flow equation. A computer program (NIST-LES3D) has been developed. The advantage of this approach is that it has been possible to move away from an iterative method of solving the flow equations. A high grid resolution has been made possible which is sufficient to 'capture' the eddies. Simulations have been undertaken with up to 400,000 grid points.

ASHRAE Symposium - Call for Papers

Air Tightness, Ventilation, Indoor Climate and Energy Performance of Small Commercial Buildings

Seattle, United States of America June 1999

Plans for a Symposium covering the air tightness, ventilation and environmental performance of small commercial buildings are currently being developed. Typical buildings include small offices (e.g. up to six floors), shopping malls, small warehouses and light industrial premises/workshops. The intention is to focus on ventilation and air tightness issues and their impact on indoor climate, energy efficiency and comfort. Papers covering the following topics are especially welcome:

- Improving the air tightness of small commercial buildings;
- Impact of air tightness measures on comfort, air quality and well-being;
- Ventilation strategies incorporating air tight design;
- Demonstration of energy performance;
- Standards or guidelines relating to air tightness requirements;
- Demonstration of retrofit and new build examples.

Papers conforming to ASHRAE requirements must be submitted to Martin Liddament at the AIVC by September 30th 1998. In the first instance please send an abstract of your proposed paper by May 31st 1998. Notes to authors will then be forwarded. Papers are peer reviewed prior to acceptance and will be published in the ASHRAE Transactions.

Further information about this ASHRAE meeting including a full list of abstracts is available from Martin W. Liddament at the Air Infiltration and Ventilation Centre.

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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, 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

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, £20.00

An Overview of Combined Modelling of Heat Transport and Air Movement, Kendrick J F, .1993, TN 40, £20.00

Infiltration Data from the Alberta Home Heating Research Facility, Wilson D and Walker I, 1993, TN 41, £20.00

Current Ventilation and Air Conditioning Systems and Strategies, Limb M J, .1994, TN 42, £20.00

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An Analysis and Data Summary of the AIVC's Numerical Database, Orme M S, 1994, TN 44, £20.00

Air-to-Air Heat Recovery in Ventilation, Irving S, 1994, TN45, £20.00

1994 Survey of Current Research, Limb M J, 1995, TN 46, £20.00

Energy Requirements for Conditioning of Ventilation Air, Colliver D, 1995, TN 47, £20.00

The Role of Ventilation in Cooling Non-Domestic Buildings, Irving S J, 1997, TN 48,£20.00

NEW!!
Energy Impact of Ventilation: Estimates for the Service and Residential Sectors, Orme M S, 1998, TN 49, £20.00

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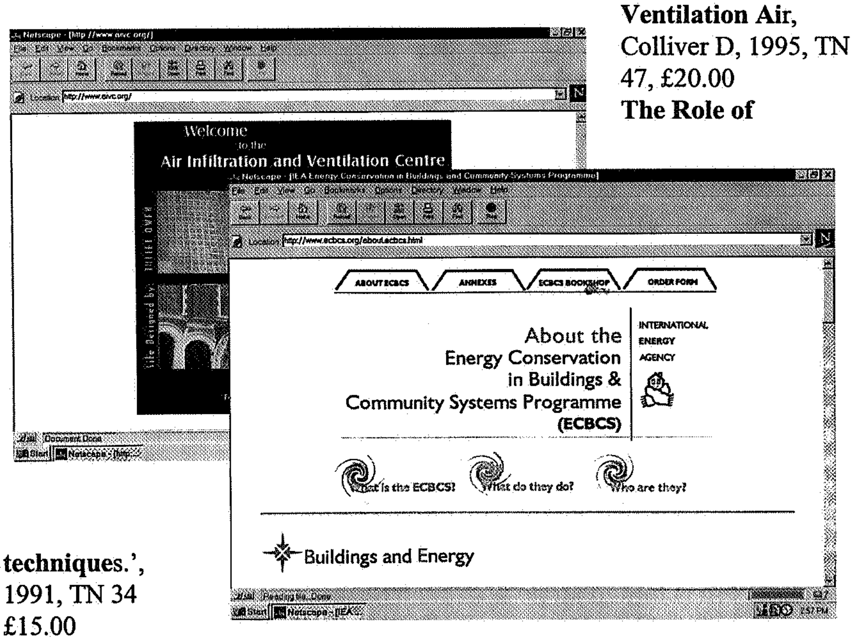
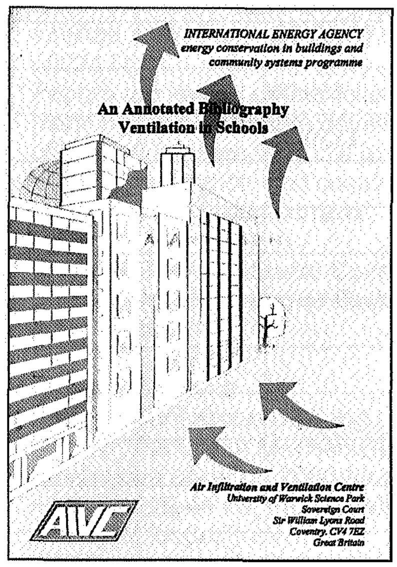
Introduction to Ventilation Technology in Large Non-Domestic Buildings, Dickson D, 1998, TN 50, £20.00



ANNOTATED BIBLIOGRAPHIES

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
Passive Cooling, 1998, BIB 8, £15.00 (Available soon)

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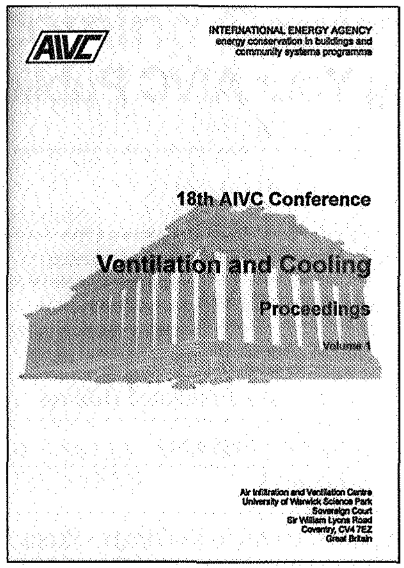
Papers from earlier AIVC Conference Proceedings are also available.



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
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'Optimum Ventilation and Air Flow Control in Buildings', Gothenburg, Sweden, 1996, CP 17 £50.00
'Ventilation and Cooling', Athens, Greece, 1997, CP 18 £65.00

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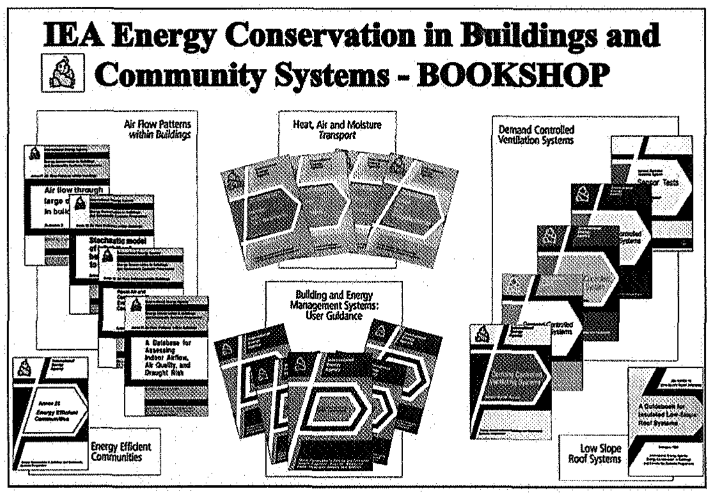

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5th March 1998
Wels, Austria
O.O. Energiesparverband, Landstrasse 45, A-4020 Linz, Austria, Tel +43 732 6584 4380, Fax: +43 732 6584 4383, email esv1@esv.or.at

Rebuild: the European Cities of Tomorrow 2nd European Conference
1-3 April 1998
Florence, Italy
ETA-Florence, Piazza Savonarola 10, I-50132 Firenze, Italy, Fax: +39 55 573425, Tel: +39 55 5002174
Papers are invited on the following topics: Urban planning for sustainable development; Protection of cultural heritage with low energy technolgies in building restoration and construction; Sustainable mobility in the urban context.

SITHOK-3 International Congress on Heating and Air Conditioning of Buildings. Energy and Environment
May 9-11, 1998
Maribor, Slovenia
Prof. Dr. Jurij Krope Dipl. Ing., University of Maribor, Faculty of Mechanical Eng., SITHOK-3, Smetanova ulica 17, 2000 Maribor, Slovenia, Tel: +386 62 229 44 75, Fax: +386 62 220 79 90, email jurij.krope@uni-mb.SI, http://www.fs.uni-lj.si/sithok
Program: energy, environment and economic; indoor environment; HVAC application in domestic and commercial buildings; HVAC&R design and computer software; HVAC&R system control; sanitary technique.

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
Papers will cover subjects related to ventilation and airflow patterns, and also heat and mass transfer within rooms under both steady-state and dynamic conditions.

Energy Efficiency in a Competitive Environment ACEEE 1998 Summer Study on Energy Efficiency in Buildings
23-28 August 1998
Asilomar Conference Center, Pacific Grove, California, USA
American Council for an Energy-Efficient Economy, Summer Study Office, 1001 Connecticut Avenue NW, Suite 801, Washington, DC 20036, USA +1 202 429 8873, Fax: +1 202 429 0193, email ace3-conf@ccmail.pnl.gov, http://aceee.org

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.

Intelligent Buildings: Realising the Benefits
6-8 October 1998
Watford, UK
Angela Mondair, The European Intelligent Building Group, BRE Events, BRE, Garston, Watford WD2 7JR, UK, Tel: +44 (0)1923 664 775, Fax: +44 (0)1923 664 688, email: mondaira@bre.co.uk
Topics: why intelligent buildings matter; intelligent building technologies; overcoming the challences; the future of buildings.

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

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