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Ventilation and Air Pollution: Strategies for Buildings Located in Urban Areas

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Introduction

With environmental issues in mind, building designers are increasingly being encouraged to consider natural ventilation as a primary design option. Naturally ventilated office buildings can typically consume less than half the delivered energy consumed in air-conditioned buildings, representing cost-effective energy savings of the order of 20-30%. Furthermore, a survey (Harris Research Centre for Richard Ellis Partnership) of major occupiers indicated that about 90% of directors and senior management preferred buildings without air-conditioning. Making the best use of natural ventilation headed the list of occupiers' most important design features.

However, in urban areas, the ingress of external contaminants from urban pollution sources, in particular from vehicle emissions, building ventilation exhausts and boiler flues, is perceived to be a major barrier to the use of natural ventilation. This perception, however, is mainly due to a current lack of information and understanding of the complex external flow regimes and pollutant sources, and the interaction of these with ventilation processes and indoor air quality in buildings located in 'polluted' urban conurbations. There is thus little recommended design guidance on how to effectively ventilate these buildings using low-energy technology while at the same time minimising infiltration of external pollution levels. Mechanical ventilation and air-conditioning systems are therefore being installed to clean the incoming air even though there is evidence that such systems do not always provide clean fresh air (1, 2). It has thus become necessary to study and understand the complex interactions of the external environment with the indoor environment, to enable the development of low energy ventilation solutions for buildings in urban locations with regard to indoor air quality and thermal comfort.

In this article, a brief account of some of the parameters that are important in understanding these interactions are given together with the work that is being carried out at the Building Research Establishment Ltd (BRE) in the UK to address them.

Building Contamination Process

Contamination of buildings from external pollution sources is strongly dependent on both wind flow (speed and direction) and dispersion processes around the buildings. These processes are complex and affected by the surrounding structures, as well

In this issue

as by the size, shape and the orientation of the building itself, and finally by the type, position and distance of the contaminant sources. The arrangement of the urban area and the distribution of contaminant sources within it are therefore important factors in the contamination process.

For naturally-ventilated buildings, it is the combination of pressure forces and contaminant levels around the building that is important in generating the internal contamination level. This level depends not only on any internal contamination sources but also on the levels of external contamination, the building's ventilation processes, and the attenuation provided by the building envelope.

Type of External Pollutants

In general, there are two types of external airborne pollutant which cause building contamination problems:

- those capable of generating adverse health effects, and
- those causing nuisance.

Both are important to the building internal environment. The most common external pollutants affecting health are acid gases (such as SO_2), NO_x, ozone and small particles. Carbon monoxide is frequently mentioned in this respect; however, it is a major pollutant only when produced in large quantities as a result of imperfect combustion. Similarly, carbon dioxide is mainly important as an indicator of ventilation performance and internal air quality. The most common sources of 'nuisance' pollutants likely to enter a building are odour and windborne dust.

In recent years a much broader-based spectrum of contaminants and contaminant sources have been recognised as being of concern in ventilation problems. These range from the conventional polluting discharges (such as those from combustion and stationary generating plants) to:

- vehicle emissions (currently considered to be a major source of urban pollution),
- process discharges (including for example, fume cupboard discharges),
- nuisance discharges (especially odours) and
- cross-contamination problems

In addition contaminants may be of gaseous or particle form and there is a growing interest in the relationship between indoor and outdoor sources of these and in particular, very small particles (below 10μm).

External Pollutant Sources

The relationship between various pollution sources from different distances, is an important factor in the type of pollutant exposure experienced by buildings. For example, the nearer a pollutant source, the greater is the variation in concentration over time and distance that will be experienced. At a particular site therefore, pollution sources from different distances combine to form the overall levels experienced, so that the overlapping of different sources is critical to the type of exposure.

A recent review by BRE discusses these issues in some detail (3). This considers the relationship between 'local' sources and overall 'background' levels of pollutants, their total contributions to the local pollution levels and the vertical and lateral gradient of pollution. The discussion is illustrated by examples from measurements of dispersing plumes and of urban pollution levels experienced during a specific investigation in a large urban area in the UK. Sample data from four sites were studied and results showed significant levels of temporal and spatial variation of pollutant concentration over relatively short distances. Correlations of this somewhat limited data, gave negligible agreement both over short distances and relatively long averaging times. Information and understanding on these small scale variations and their effect on buildings is currently limited; work at BRE is being continued to address this.

Results from Studies at BRE

BRE has carried out a short term pilot study over a one week period (4) to investigate the following:

- internal and external pollution levels of a naturally ventilated and a mechanically ventilated building in close proximity to one another,

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Editor: Janet Blacknell

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- their relative attenuation of external pollution levels, and
- a comparison of the levels recorded indoors with currently available air quality guidelines.

The buildings studied were located adjacent to each other and overlooking a major road in the centre of Birmingham, a large UK urban city. Both buildings were used normally as offices with expected variable occupancy and normal office activities. Both offices had a no-smoking policy and there were no gas appliances or any other significant internal sources of the measured pollutants. Measurements of carbon monoxide (CO), oxides of nitrogen (NO_X), sulphur dioxide (SO_2), carbon dioxide (CO_2), building air change rates and traffic density were made in parallel in both buildings.

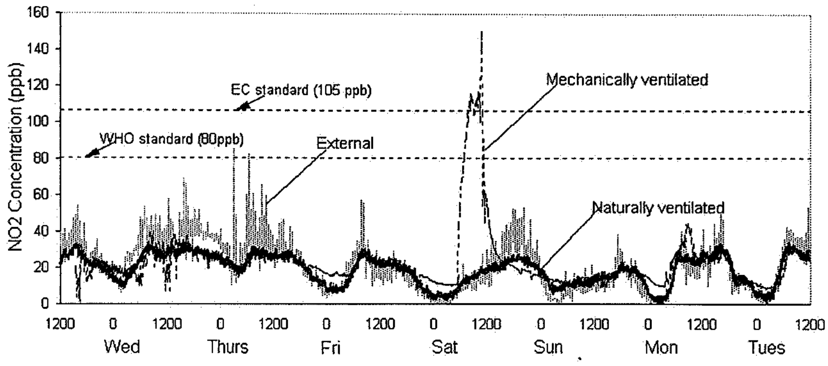


Figure 1: Nitrogen dioxide concentration, ppb (Birmingham, UK: 13-20 Feb 1996)

The short period of monitoring in this study allowed only a limited scope for investigation of the performance of the buildings with regard to the indoor and outdoor air quality. However, a number of interesting observations were made about the attenuating capability of the buildings and the comparison of the internal measured pollutant concentrations with existing air quality guidelines.

1. In both the naturally and mechanically ventilated buildings the indoor air quality followed the trend of that of the external air to which they were exposed. However, the concentrations of the external pollutants were attenuated by the building and the transient peak concentrations measured externally were approximately halved in value.

Measured gas	Measured mean concentrations		Air quality standards/guidelines				
	Naturally ventilated	Mechanically ventilated	DoE*	EPAQS+	WHO#	EA##	EC~
CO (ppm)	1.7	0.9	-	10[1]	10[1]	50	-
CO_2 (ppm)	650	646	-	-	-	-	-
NO (ppb)	97	78	-	-	-	830	-
NO_2 (ppb)	28	25	<50	150[2]	80[1]	100	105[1]
SO_2 (ppb)	4.4	3.9	<60	100[3]	122[2]	170	94[2]

Table 1. Measured mean concentrations inside the buildings for the working week compared with existing air quality guidelines.

* Department of Environment - very good air quality
\+ Expert Panel on Air Quality Standards
\# World Health Organisation
\## UK's Environment Agency short-term exposure limit
~ European Community guidelines
1 8-hour mean
2 1-hour mean
3 15-min mean

2. The daily mean concentrations of the gases measured in both buildings over the main occupied period did not exceed any of the main health standards (Table1). However, most of the NO_2 guideline values were exceeded over the weekend when combustion products were possibly drawn into the mechanically ventilated building (Figure 1). This illustrates the possible danger of cross-contamination between ventilation exhausts and inlets at roof level.

3. In the two buildings studied, there appeared to be no clear distinction between the two ventilation strategies in providing adequate indoor air quality with respect to externally generated gaseous air pollutants other than when combustion products were entrained into the mechanically ventilated building.

This study has highlighted a real need to address issues related to external air pollution and its sources and the way they affect the internal environment of buildings in urban areas whatever strategy is used in ventilating a building.

Current Work at BRE

Currently, research at BRE is addressing how the fundamental parameters detailed above affect the indoor air quality in naturally ventilated buildings located in urban areas. We are studying the complex behaviour of external pollutant sources and flows, dispersion of these and their interactions with the cities' infrastructure and their subsequent effect on the internal environment of buildings.

This is being done both through full scale monitoring studies to investigate the pollution levels inside and outside buildings in polluted urban areas and through small scale experimental studies. The latter concentrates on wind tunnel simulations of the dispersion of local pollutants around buildings and the wind pressures that generate infiltration. The data obtained will be coupled with assessments of the effects of various pollution sources at different distances to the total exposure experienced by buildings.

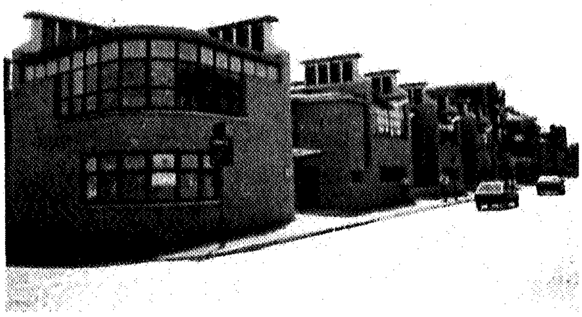


Figure 2: The Canning Crescent Centre

As part of the full scale monitoring, the Canning Crescent Centre (Figure 2) located on a busy street in London is at present undergoing detailed monitoring. The effect of the building envelope and its natural ventilation strategies on external pollution levels found indoors and the variation of these with space and time are being investigated. Furthermore, we are also studying various buildings in the city of Manchester. We will use the results of these and our other studies to develop appropriate solutions for effectively ventilating buildings located in urban areas where external air pollution may be a problem. Further details of work being carried out at BRE in this important area may be obtained from Dr Vina Kukadia on 01923 664878,
email: kukadiav@bre.co.uk.

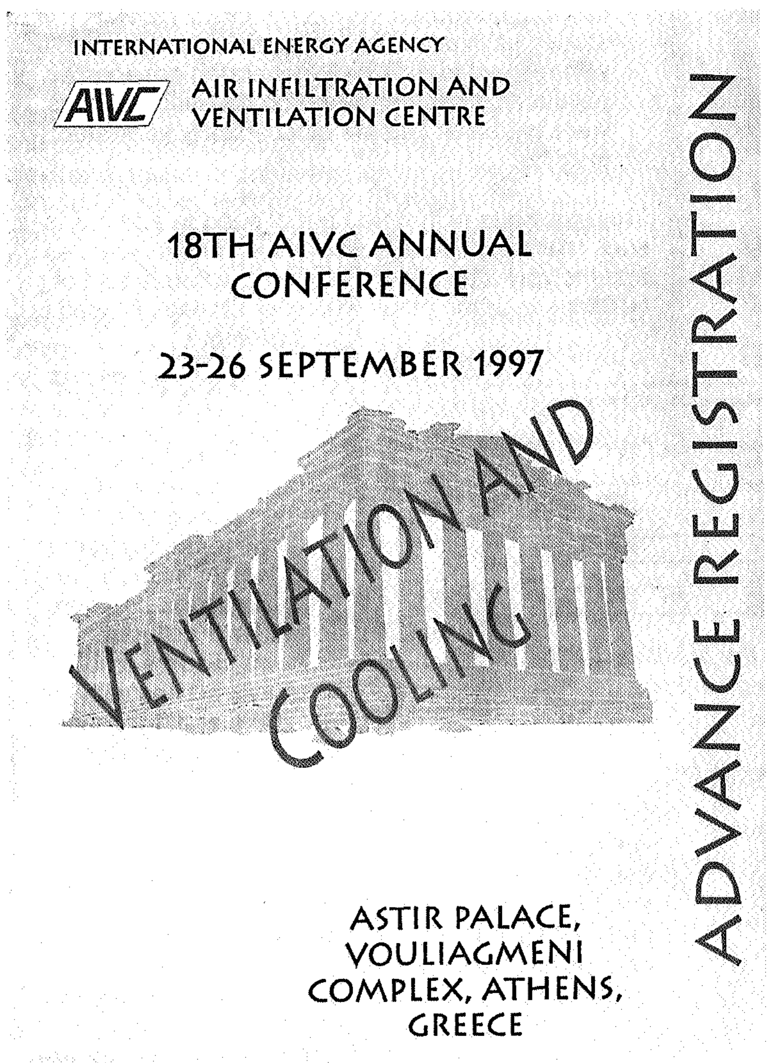
References

1. R H Morris, *'Indoor Air Pollution' Heating/Piping/Air Conditioning - February 1985*

2. V Kukadia and J Palmer, *The Effect of External Atmospheric Pollution on Indoor Air Quality*. 17th Annual Air Infiltration and Ventilation Centre Conference, Sweden September 1996.

3. DJ Hall, AM Spanton, V Kukadia, S Walker, *Exposure of Buildings to Pollutants in Urban Areas - A Review of the Contributions from Different Sources*. BRE report CR 209/96.

4. V Kukadia, J Palmer et al. Ventilation in urban areas and city centres. Proceedings of CIBSE/ASHRAE Joint National Conference, Harrogate, October 1996.



If you wish to attend the 18th AIVC Annual Conference, please contact the AIVC as soon as possible to reserve your place.

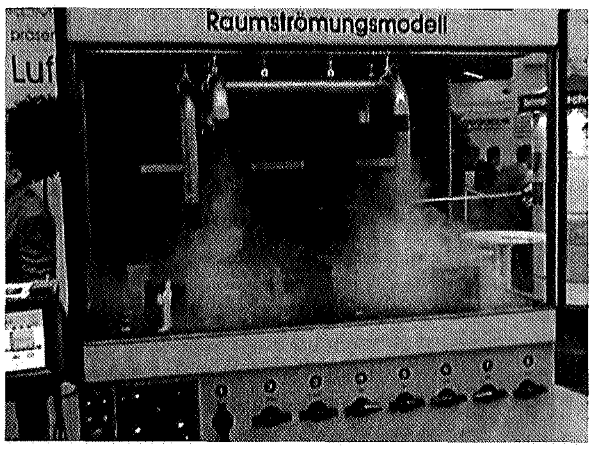
Full Conference Package £675 including three nights accommodation, breakfast, some meals, Conference Banquet and proceedings.

New Products at 'ISH'

The 'ISH' International Trade Fair is held in Frankfurt, Germany every two years and is one of Europe's largest exhibitions of HVAC equipment. During the event, over 230,000 visitors from 130 Countries attended. Many exhibitors used this opportunity to demonstrate new items aimed at improving energy efficiency and addressing indoor environmental problems. Items included:

Demonstration of Ventilation Systems

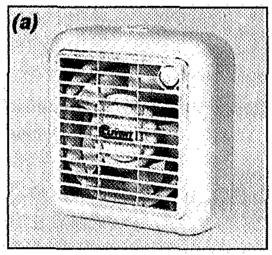
A substantial range of ventilation options is now available with the result that it is often difficult to perceive the advantages and disadvantages of each. To overcome this, *Krantz* has developed a portable ventilation demonstration chamber in which alternative ventilation strategies can be configured and compared. It incorporates a wide combination of air inlet and outlet locations combined with the choice of mixing and displacement ventilation approaches. The internal space can be configured either as an office or an industrial space with localised heat sources. Smoke is used to demonstrate the various flow patterns. Apart from demonstrating flow behaviour, risks such as short-circuiting between inlets and outlets can be assessed.

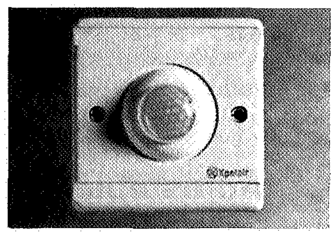


Ventilation Demonstration Chamber by Krantz

Demand Controlled Ventilation

In the past, demand controlled ventilation systems have concentrated on monitoring the build up of pollutant concentration (e.g. by using carbon dioxide or 'mixed' gas sensors). Several manufacturers demonstrated the use of Passive infra red detectors ('PIR' systems) to control ventilation. These trigger a ventilation system or fan in the presence of people, usually followed by a 'run on time', after the location has been vacated, of 20-40 minutes. This approach offers the advantage of being immediately responsive to the presence (and absence) of people as opposed to conventional systems that operate after pollutant concentration has reached a threshold level. One such example 'Clivent', is built directly into an extractor fan, while Xpelair offer a 'remote' PIR system.

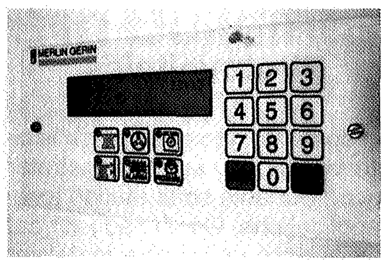




PIR Controlled Ventilation:
(a) Clivent Extractor Fan
(b) Xpelair Remote Sensor

Building Automation and 'Domotics'

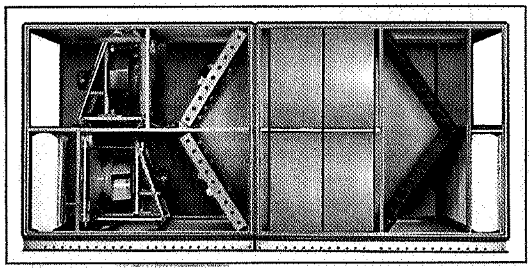
Building automation through the integrated computer control of all technical functions in a building is continuing to expand. An area of particular growth is 'domotics' i.e. the use of automated systems in dwellings. Within Europe, various companies have installed an trialed such systems covering the control not just of ventilation and heating but also, security, lighting and domestic appliances. Further developments in this field are reviewed in a European marketing report produced by Istitut Cerda of Spain (1), while a demonstration case study involving the use of domotics is described in reference (2).



User Interface for Domestic Energy Management System (Merlin Gerin)

Heat Recovery - Advances in 'Regenerative' Heat Recovery Systems

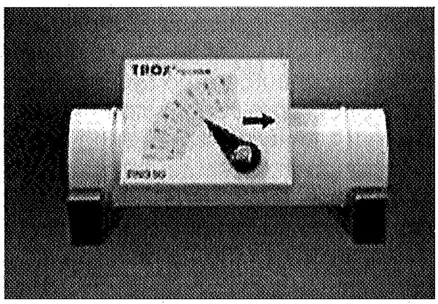
'Regenerative' or 'recuperative' heat recovery systems alternately switch the exhaust and fresh air streams through chambers of high thermal mass. In the first half of the cycle, the exhaust chamber is heated by the outgoing air. In the second half, this heated section becomes the supply chamber and releases its heat to the supply air. Efficiencies in excess of 90% have been achieved. Such a system, produced commercially by Menerga energy systems, was demonstrated at the ISH Trade Fair.



Regenerative Air to Air Heat Recovery System by Menerga

'Adjustable' Constant Flow

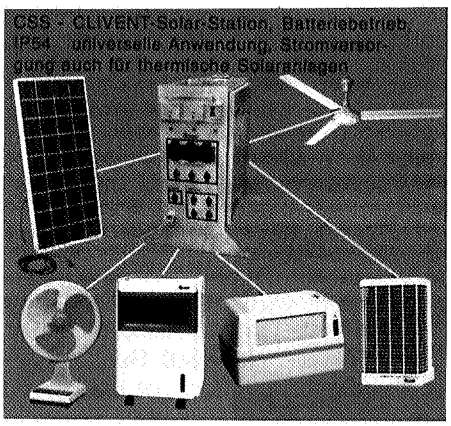
TROX demonstrated its relatively inexpensive adjustable constant volume air flow duct. This is produced in several sizes, each of which comes with a calibrated adjuster (see illustration). Near uniform air flow is maintained over a wide range of pressure drop. This has important applications in many ventilation installations because it can ensure the accurate delivery of air in complex systems.



Adjustable constant flow device by TROX

Photovoltaics

As production costs fall, increasing use is being made of photovoltaics. Clivent demonstrated their recently introduced portable solar station for ventilation and cooling applications. Combined with battery charging facilities each unit is able to deliver a peak 800W load and a continuous 300W. Add-on equipment includes air circulation fans, a small air cooler, a filtration system and humidifier.



CLIVENT Solar Station

References

(1) Institut Cerda, Pelai 16-5, E-08001, Barcelona. Tel: +3433179091, Fax: +3433025909

(2) Energia Demo Technical Report 41, from Institut Catala d'Energie, Av. Diagonal 453 bis, atic, 08036 Barcelona, Fax: 934197253

For Further Information

For further information on any of these products, please contact Martin Liddament at the AIVC.

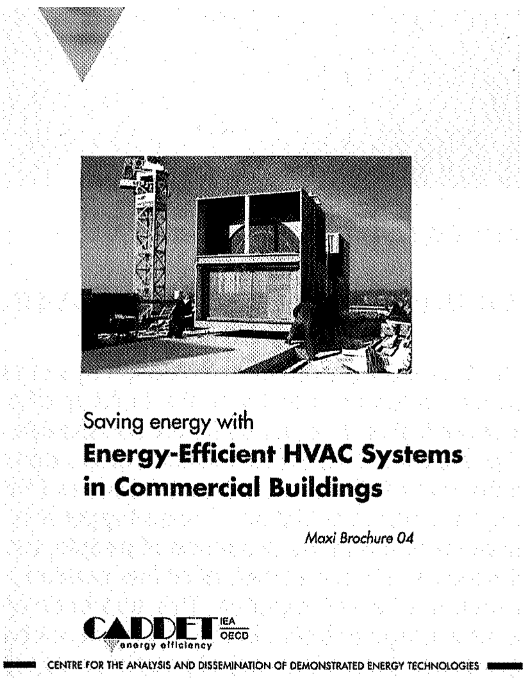
Other News

IEA-CADDET Maxi Brochure:

"Saving Energy with HVAC Systems in Commercial Buildings

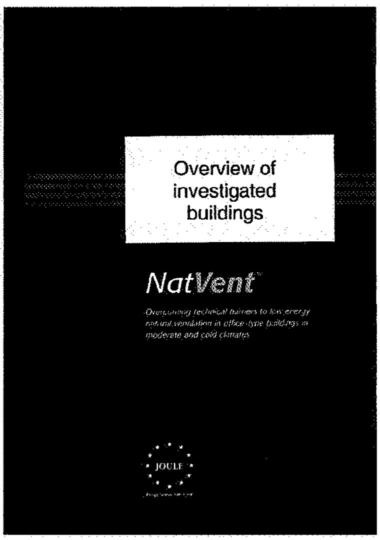
The IEA's Centre for the Analysis and Dissemination of Demonstration End Use Technologies has recently published a maxi brochure concerned with the use of energy efficient HVAC systems in commercial buildings. It focuses on emphasising the need for implementing a proper methodology covering the design process for both new buildings and the renovation of existing buildings. This is aimed at giving a clear indication of whether or not planned measures or designs really will be efficient or if they will adversely affect other parts of the energy system. Several demonstration projects are analysed.

Further Information is available from CADDET, PO Box 17, 6130 AA Sittard, The Netherlands, +31 46 4202224, http://www.caddet-ee.org



NatVent - Overview of Investigated Buildings Report

(Edited by David Ducarme, Division of Building Physics and Indoor Climate, Belgian Building Research Institute.)



The European 'NatVent' natural ventilation project, run under the 'JOULE' Programme, has recently produced an overview of the naturally ventilated buildings being monitored as part of this study. The purpose of this seven nation study is to reduce primary energy consumption by providing solutions to barriers which prevent the uptake of natural ventilation, and accelerating the use of natural ventilation (Air Infiltration Review, Vol 18, No 2, 1997). A total of 19 non domestic buildings (offices and educational buildings) are described in this report. Monitoring is taking place to evaluate the performance of existing adhoc buildings which have been designed specifically to take advantage of natural ventilation. The intention is to identify any shortcomings and advantages of such strategies with particular emphasis on determining the design and construction measures needed to achieve successful natural ventilation.

Copies of this report and descriptive brochures about the NatVent project are available directly from the AIVC library.

FGK Produce a Series of Ventilation Information Bulletins

FGK of Germany has produced a series of information bulletins covering various aspects of ventilation. These cover energy efficient ventilation solutions for all types of buildings. In addition they review the use of ventilation heat recovery devices and deal with problems associated with urban pollution. Further details are available from Fachinstitut Gebaude-Klima, Danziger Strasse 20, D-74321 Bietigheim-Bissingen, GERMANY

New AIVC Publication - Available soon from AIVC Information Service

Ventilation and Acoustics in Buildings: An Annotated Bibliography

by Mark Limb

Aimed at researchers, designers and engineers seeking an overview of current developments into acoustic control within buildings and their impact on current ventilation practices, the document analyses over fifty of the most important publications in the area.

The definition and control of noise have become important issues in recent years. To be able to provide an acceptable indoor environment, not only in terms of indoor air quality, but also acoustically, is now an important element of the overall design process. Far reaching legislation exists to restrict and control the noise output from HVAC systems and individual components, noise transmission between rooms and to and from the building to outdoors. This analysis includes an examination of current design guidance and advances in acoustic measurement and calculation, as well as research into noise generation and control in building, with the emphasis on both noise transfer by the building itself (structural elements, design or occupants), as well as HVAC generated noise (including noise transfer from the plant room, ducts, terminal devices etc.). The report concludes with an examination of the interaction of noise related problems with sick building syndrome and its impact on the quality of the indoor environment.

Contents:

- Design guidance
- Noise transmission throughout a building
- Buffer rooms and atria
- Theory into practice: opera house and auditoria case studies
- HVAC system noise
- Acoustics and indoor air quality
- Acoustic measurement and calculation methods
- Novel uses for acoustics in buildings

Climatic Data for Building Services and Simulation - CIB Task Group 21

by Malcolm Orme, Air Infiltration and Ventilation Centre

The Inaugural Meeting for the CIB (Conseil International du Bâtiment) Task Group 21, "Climatic Data for Building Services and Simulation", took place recently on the 7th and 8th April, 1997, and involved delegates from Europe, Japan, and the USA. The location for the event was the Department of Building Engineering, UMIST, situated in Manchester in the United Kingdom.

Task Group Objectives

After an introduction by Wim Bakens, Secretary-General of CIB, Geoff Levermore (UMIST, UK) outlined the general scope and priorities of the Task Group. In fact, by the concluding session of the meeting, Geoff Levermore had been able to deduce from participant responses that the likely specific areas of interest of the Group would be climatic data for building simulation, energy analyses and natural ventilation, as well as weather data quality.

Design Weather Data and its Availability

Included in the opening session were accounts of recent work from both the USA and Japan. Don Colliver (University of Kentucky, USA) discussed research projects that ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers) has undertaken relating to design weather data. Furthermore, he explained how missing data encountered in data series had been treated, in particular concluding that linear interpolation between adjacent measurements was the most appropriate method for temperature measurements. Hiroshi Akasaka (Kagoshima University, Japan) outlined the availability of Japanese climatic data and gave examples of where they had been applied in building simulations. In a later session, Hans Lund (Technical University of Denmark) indicated for which locations across Europe and certain parts of the Middle East design reference years (DRY) and test reference years (TRY) can be obtained.

Several presentations were made with regard to availability and quality of meteorological data sets. Examples of large-scale data sets (CD-ROM based) identified at the meeting were SAMSON, containing data series for 239 locations across the USA, CWEEDS containing data series for 143 Canadian sites, and AMeDAS which includes data for 845 Japanese meteorological stations. On the subject of data quality, the issue was raised of whether hourly weather data actually express an average taken for each whole hour, or just an average for some shorter time period.

Thermal Performance of Buildings

Alan Jones (EDSL, UK), from among a number of presentations considering thermal aspects of buildings, highlighted that the 'admittance procedure' assumes heat saturation of a building. This procedure is often used to calculate building internal temperatures during the cooling season. In practice, he stressed, a period of perhaps over three weeks may be needed before saturation is completed, during which time a large thermal mass may be beneficial for cooling a building. On a related topic, Chris Sanders (BRE, UK) drew attention to the activities of CEN/TC89 ("Thermal Performance of Buildings and Building Components") Working Group 9 "Climatic Data". They are devising standard procedures for calculations ranging from the evaluation of monthly averages of single meteorological elements to selecting climate data for cooling system assessment. In addition, he announced that the European Solar Radiation Atlas will soon be published. Also at the meeting, Geoff Levermore explained the ways in which the CIBSE (Chartered Institute of Building Services Engineers) 1997 Handbook Volume J (formerly Section A2 in the 1982 CIBSE Manual) has been updated.

Contact Information

For further information about CIB Task Group 21, please contact: Dr. Geoff Levermore, Senior Lecturer, Department of Building Engineering, UMIST, P.O. Box 88, Manchester M60 1QD, United Kingdom

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New Publication

Reducing Occupant Exposure to Volatile Organic Compounds (VOCs) from Office Building Construction Materials: Non-Binding Guidelines

by Leon E Alevantis, M.S., P.E.

Indoor Air Quality Section, Environmental Health Laboratory Branch, Division of Environmental and Occupational Disease Control, California Department of Health Services

June 1996

Resulting from concern about increasing complaints of sick building syndrome (SBS), the California Department of Health Services has undertaken to develop nonbinding guidelines for the reduction of exposure to volatile organic compounds (VOCs) from construction materials in newly constructed or remodeled office buildings. Researchers have reported that VOCs play a role in many SBS complaints, particularly in new or newly renovated office buildings, which often have substantial amounts of building and furnishing materials that emit VOCs.

The guidelines consider building construction materials to include not only construction materials and products but also major furnishings, such as office workstations, installed as part of a building's overall architectural and interior design. In addition, the guidelines address those cleaning and maintenance materials and products, the use of which is directly associated with the building construction materials and products selected.

The guidelines provide the best currently available information on minimizing occupant exposures to VOCs from office building construction materials. They have been written primarily for application to office buildings of any size that use mechanical heating, ventilating, and air conditioning (HVAC) systems. However, they can be applied to most building types such as mixed-use buildings (e.g. libraries and courthouses). In addition, elements of the guidelines can be applied to naturally ventilated buildings.

A five-step approach to reducing exposure to VOCs from building materials and products is recommended. These five steps are:-

Step 1
Evaluate and select low-VOC-impact building materials and products

This is the most critical step in minimizing human exposure to VOCs emitted from building materials and products. In order to assess the impact of emissions from building materials, the guidelines define a low-VOC-impact building material or product as one that when installed in a building results in minimal or reduced exposure of occupants to VOCs that are emitted from the material or product.

Task 1 - Identification of target materials and products based on estimated installed quantities, proximity of installed materials and products to occupied zones, adsorption characteristics of some materials, and identification of materials and products with known high VOC emission rates.

Task 2 - Collection of more detailed VOC related product information on candidate materials and products using manufacturers' lists of Material Safety Data Sheets (MSDSs), product specifications listing chemical contents, results of emissions testing data, and other sources such as lists of carcinogenic contents.

Task 3 - Evaluation of building products and materials based on MSDSs, reactive VOC contents, calculated chemical emissions using vapour pressures and mass transfer coefficients, results of emissions testing, and estimated indoor concentrations.

Task 4 - Selection of building products based on MSDSs and/or emissions testing results. Selection of products based on MSDSs alone is complicated by the lack of indstry standardisation of the reported information, and the fact that MSDSs are sometimes incomplete or inaccurate failing to list all potentially hazardous substances.

Step 2
Pre-condition certain materials to minimize VOC emissions after installation

This step includes conditioning of materials at the manufacturing or assembly facility, at a "bonded" warehouse with appropriate ventilation, or in a dry, well-ventilated area other than the one where the materials will be installed, until emissions have been reduced. Examples of these materials include office furniture and carpeting. Note that storage of certain materials after manufacturing is unavoidable especially in cases of special production orders or large quantities. For example, in the case of carpeting for a large-size building, there may be a time lag of several months between production and delivery of the product. In such cases storage is unavoidable and specifying a dry, well-ventilated space may not add a considerable cost to a project. There are no field data demonstrating the minimum length of time needed to effectively precondition various building products.

Step 3
Install building materials and products based on their VOC emission decay rates

This step involves the phased installation of building materials and products based on their emission and adsorption characteristics. Typically wet products such as paints, adhesives, and taping and deck leveling compounds should be installed first. Wet products are typically characterised by very high initial emissions followed by much lower emission. This is because most solvents and other chemicals in wet products are emitted for a few hours or days after installation. Porous materials, such as carpets and fabric-covered office dividers, should be installed last. This technique minimises adsorption by porous materials of the VOCs initially emitted by wet products and subsequent re-emission at a later time (a process known as the sink effect)

Step 4
Ventilate a building during and after installation of new materials and products

The maximum amount of outside air should be provided during and after installation of VOC emitting materials for the maximum amount of time feasible (this process is known as a building flush-out). There are no data on the recommended duration for building flush-outs, but a conservative approach is to flush-out as long as economically feasible, but not less than continuously (i.e., 24 hr) for seven days. It should be noted that the maximum amount of ventilation provided by an HVAC system may be limited not only by the system's capacity but also by the temperature and humidity of the outdoor air. Special procedures during partial building renovation/remodeling (i.e., completely isolating the air between occupied areas and areas under construction) should be followed and are discussed. The guidelines summarise and encourage compliance with ASHRAE's recommendation on HVAC commissioning (i.e., a process that ensures that the performance of an HVAC system meets design parameters) in order not only to minimise exposure to VOCs but also to improve indoor air quality during the life of a building.

Step 5
Delay occupancy until VOC concentrations have been reduced adequately

Because VOC concentrations are highest during and immediately after construction, it is important to allow sufficient "flush-out" time before occupants move in. Air samples can be taken to verify that indoor VOC concentrations have been reduced sufficiently prior to occupancy. It should be noted that: a) guidelines exist for only a few VOCs; b) there are no standard testing methods for TVOCs; and c) existing guidelines for TVOCs are not widely accepted. However, TVOC concentrations can be used to compare a buildings's indoor air with measurements taken in other non-problem buildings.

A detailed economic analysis of all the costs associated with the above five steps is beyond the scope of the guidelines. However, some of these costs are discussed. Unfortunately there is very limited published information on this subject. Based on this limited information, it appears that the highest cost of reducing occupant exposure to VOCs is associated with emissions testing of building materials, especially when many products must be tested. The cost of testing individual products based on the Headspace sampling technique ranges between $1,000 and $2,000, whereas the cost of testing large-size products, such as complete office workstations, in envrionmental chambers exceeds $5,000 depending on many factors such as test duration, number of test air change rates, number of samples tested, etc. Other costs, such as design fees, cost of building materials, cost of increased ventilation, and cost of delayed occupancy, also need to be considered. Limited data indicate that design fees are low, accounting for less than one percent of the Architectural/Engineering fees of a project. Although the cost of building materials account for a major portion of the construction cost (typically between 30 and 60 percent), their cost is usually independent of their emission characteristics (i.e. lower VOC emitting materials are likely to be reduced or eliminated as demand for these products increases. Finally, other costs such as those resulting from increased ventilation and delayed occupancy are project-specific. It is important for building owners and employers to realise that if poor indoor quality increases the absenteeism rate by only 2.5 percent (OSHA estimated this rate to be 3 percent) then the increased annual costs associated with this increased absenteeism rate is comparable to the cost of utilities or maintenance and operation of a building. Other economic impacts of improved indoor air quality also must be considered. These include reduced liability exposure, improved building marketability, reduced health care costs, lower operating costs, and increased occupant comfort and productivity.

Availability

Copies of the guidelines are available from Leon Alevantis, Air Pollution Research Specialist, State of California, Dept of Health Services, Indoor Air Quality Section, 2151 Berkeley Way, Berkeley, CA 94704-1011, USA, Or from the AIVC Library.

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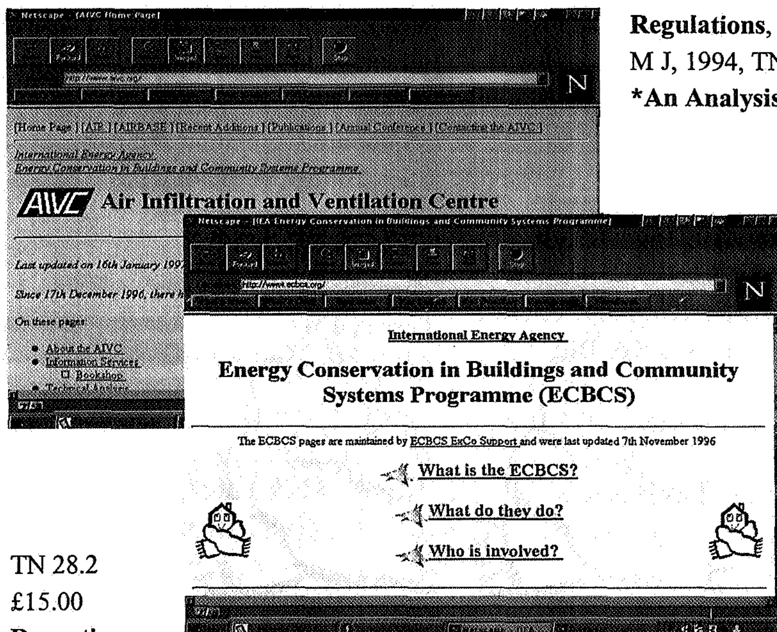

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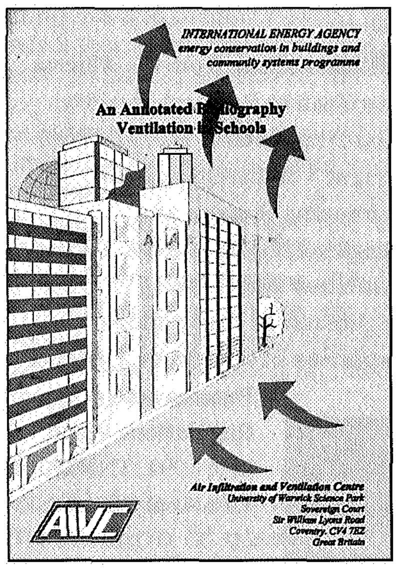

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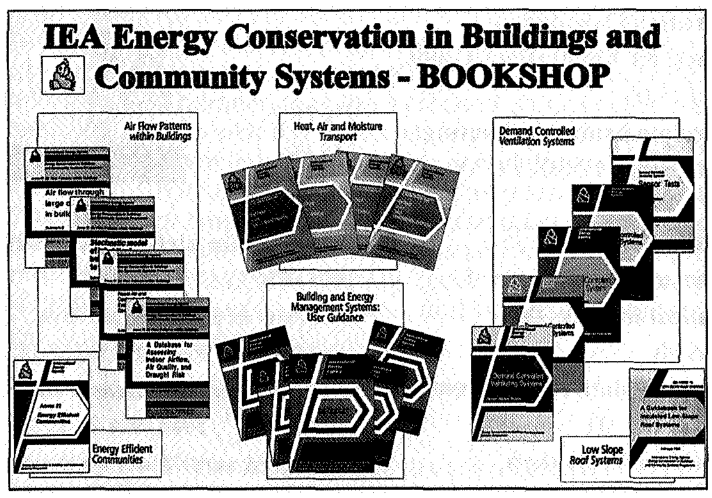

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