Air Infiltration Review

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International Energy Agency - AIVC

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Ventilation System Performance - 11th AIVC Conference

18 -21 September 1990, Hotel Villa Carlotta, Belgirate, Lake Maggiore, Italy

By Mark J Limb, Air Infiltration and Ventilation Centre

The theme of the 11th Air Infiltration and Ventilation Centre's conference focused on the performance of new ventilation technology. This addressed the need both to achieve greater thermal performance in buildings and to improve indoor air quality. Greater consideration is also being given to the needs of occupants and how systems and occupants interact. Attention is also being drawn to the way systems meet the needs of the consumer, and how international ventilation standards are helping to improve ventilation and indoor air quality throughout the world.

This conference attracted over 80 experts from 14 countries. The conference was divided into three formal presentation sessions and three display sessions, spread over four days. In total, 48 papers were presented, covering a variety of ventilation systems as well as measurement, monitoring and calculation techniques.

The keynote speaker was Mr. Alex Sandelewski, of TEKNE SpA, a leading consulting engineering firm based in Milan. In his address he highlighted the interaction between a building's ventilation system and its occupants, and many of the pitfalls that surround an engineer of such systems. Despite the existence of ventilation standards, which are very often adhered to, the engineer still receives complaints. Several scenarios have shown that textbook knowledge and experience sometimes are not sufficient to prevent the building illnesses familiar today. Still the most volatile components in a HVAC system are the occupants. His

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speech pointed out the interaction between everyday people and professionals, and that the aim should be to close the gap between researchers, designers, manufacturers and the consumer, and to allow and encourage communication between these people.

Building Management Systems

Following the keynote presentation a number of papers covering various aspects of building management systems and their interaction and effects on occupants and on indoor air quality were presented. This was followed by detailed descriptions of specific systems including humidity / carbon dioxide controlled systems (from Finland), work station (task) and localised floor ventilation solutions (both from the USA). The demand controlled options presented by Reijo Kohonen of Finland, focused on the functional requirements of the system and some of the technical solutions for trouble free demand controlled ventilation in dwellings. Two papers from the United States described two types of localised ventilation systems. In the first, a task ventilation device, where the occupants of work stations are able to alter the direction and amount of fresh air they receive was presented by William Fisk from Lawrence Berkeley Laboratory, USA. The second paper by Ed Arens, from the University of California, described several methods to alleviate thermal comfort problems in offices by the installation of localised floor ventilation devices allowing the occupant of any desk space to alter the amount of ventilation they receive.

Display Sessions

The second day was divided into two display sessions in which each author gave a short five minute presentation of his work. This was followed by an opportunity for delegates to study the posters and to discuss aspects of the papers with the authors at some length. Towards the end of each session the delegates gathered again, for some open discussion on various points raised by the posters. The first of these sessions covered the measurements using tracer gas technology and numerical work involving modelling. Several authors discussed tracer gas techniques used to achieve many of their results. R Rabenstein from the University of Siegen, Germany, outlined an air change measurement system named MULTI-CAT (Multichannel Concentration Analysis of Tracers), providing a man-machine interface through a computer program, which instructs the user how to use tracer gas equipment in the field, and how to produce a readable standardised report. Other authors showed how tracer gas technology was being used in their measurements to clarify and depict the air change within a room or building. Among these authors were Peter Wouters (from the Belgian Building Research Institute), M. Cali (from the department of Energy, Turin, Italy) and Saffa Riffat (from Loughborough University, UK).

Display sessions prompt active debate

Four papers were presented detailing numerical modelling procedures. Richard Grot, from Lagus Applied Technology, USA, displayed an interzonal air flow model, which aroused much interest among delegates. G. V. Fracastoro from the University of Basilicata, Italy, described a mathematical model,

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Editor: Janet Blacknell

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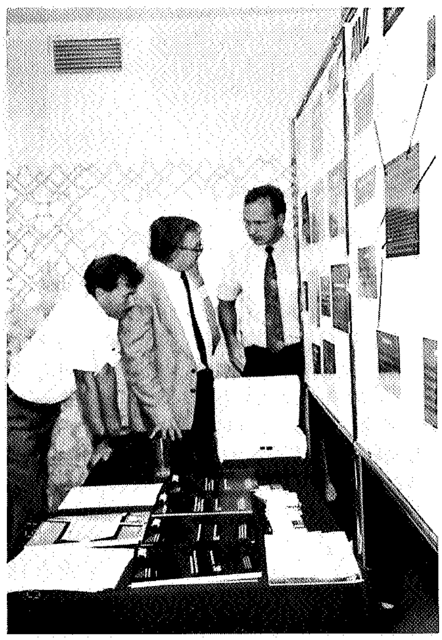
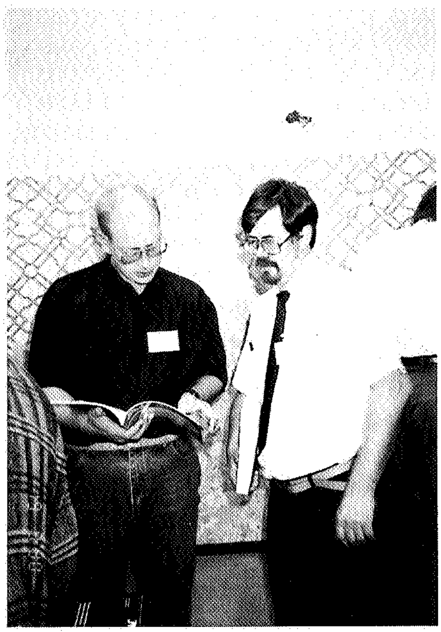
which is used to analyse the thermo-fluid dynamic interactions between a building and heating system. The modelling theme was carried over into the second display session. The content covered work on computational fluid dynamics (CFD), several case studies, and the use of models in the evaluation of better indoor air quality.

During the poster sessions, the AIVC's database, AIRBASE was demonstrated and displayed, using a desktop computer. The AIVC also displayed two posters throughout the conference. The first contained the AIRBASE display, and a slide show explaining how the database software is manipulated. The second display showed the work of the Centre on a wider footing, describing its technical notes, and the dissemination of research knowledge that is carried out by the AIVC, on a worldwide level.



Display session; AIVC's poster is discussed

The main theme of the second presentation session was demand controlled ventilation. Five papers were presented on this subject, four of which were from Belgium, Germany, Italy and the Netherlands, all participants in IEA Annex 18, on Demand Controlled Ventilating Systems (DVC). The final paper covered humidity controlled systems in France and was presented by Dominique Bienfait from CSTB, France. In his presentation he reviewed the most popular residential ventilation systems used in France, explaining their design and use, and some of their specifications. Dominique also touched on DCV systems and their potential use in France. Peter Wouters from Belgian Building Research Institute, outlined experiments comparing humidity controlled ventilation systems in an apartment block in Belgium with an identical block without DCV. He concluded that DCV systems do work, but further work needs to be undertaken to perfect existing systems. This theme was carried over in a paper by Michael Szerman of the Fraunhofer Institute of Building Physics, Germany who described a humidity controlled ventilation device based on the principle of free ventilation. The sensor controlled device automatically opens and closes without the need for external power. Gian Fracastoro, from the University of Basilicata, Italy, explained in his presentation that despite the fact that mechanical ventilation is seldom used in Italy, the weather in the north in winter is moderately cold and humid, making DCV systems a potentially viable option. He also described measurements being made in conjunction with IEA Annex 18, on DCV systems in this part of Italy. Professor Hugo Hens from the University of Leuven, Belgium, presented the final report of IEA Annex 14 (Condensation and Energy) and discussed several associated case studies. Professor Hens reviewed the original background and the main theoretical principles that lead to this study. A particular case study which exemplified the annex's work was described in some detail. The paper examines the curing procedures that were carried out on one house on the Zolder housing estate and outlines the associated results. The final paper in this session was presented by Willem De Gids from TNO, Netherlands, who described the results of measurements in dwellings with various ventilation systems, both natural and mechanical and how occupant behaviour can be influenced by the presence of such systems.



Delegates discuss the finer points of demand controlled ventilation

The second presentation session was followed by the final poster session. Nine papers were presented covering a wide spectrum of work. These included a presentation from Japan, in which the numerical and experimental analysis on flow and diffusion fields within a room, was described, a video demonstration of the results aroused much interest. Several display papers continued the theme of Humidity controlled systems, their applications and measurements (presentations encompassing DCV systems were from Reijo Kohonen, from the Technical Research Centre of Finland; Hans Werner from the Fraunhofer-Institut Fur Bauphsik, Germany and Heinrich Trumper from University of Dortmund, Germany). Mohammad Zainal from Reading University, UK, described measurements in a naturally ventilated lecture theatre. Results indicated that by varying the window opening position, ventilation characteristics could be altered. Window opening behaviour along with air change rates and indoor air quality was further examined by a paper Jurg Fehlmann of the Department of Hygiene, Switzerland. Goran Werner, from AIB, Sweden outlined the results of experiments which were presented at the ninth AIVC conference in Gent, 1988. In which well insulated airtight buildings in Stockholm, Sweden with integrated air heating and ventilation systems were used, and the indoor climate and temperature was measured. This paper presents further results from this study.

The final presentation in this session was given by James Piggins of the AIVC, who described work on a standardised set of reporting guidelines for recording ventilation and associated measurements.

Ventilation Efficiency

During the final presentation session five papers were presented. The main topic of discussion was ventilation efficiency and a return to tracer gas methods. The first paper was presented by Claude Alain Roulet, describing the work by LESO-EPFL, Lausanne, Switzerland. A simple measurement method using tracer gases to identify the main air and contaminant paths within a room was discussed. Martin Liddament of the AIVC presented a paper by Helen Sutcliffe and Robert Waters, of Coventry Polytechnic, UK, which detailed some of the likely errors associated with the measurements of local and room mean age of air, using tracer gases. Ventilation effectiveness and tracer gas methods were discussed in a paper by Andy Persily from National Institute of Standards and Technology, USA. He discussed measurements in a library/office complex. Tracer gas analysis was carried out in a real building, where a tracer was injected into air handling equipment of the building until an equilibrium situation was established. The results were used to establish ventilation effectiveness. Earle Perera from the Building Research Establishment in the UK, also described tracer gas measurements in a single cell factory unit. Measurement results were then compared with predicted results using the BREAIR model. Measured values were found to compare well with those predicted. The final conference paper was presented by J Hensen of the Netherlands who described a joint project between himself and Professor Joe Clarke of the University of Strathclyde. The paper outlined some of the techniques used within the ESP system to present and solve the heat and mass conservation equations relating to combined building and plant systems.

Richard Grot demonstrates numerical modelling procedures

The conference concluded by a summing up, from David Harrje, who successfully brought together the subjects and ideas discussed at this meeting. He especially reminded participants that good communication is needed, not only between the researcher, designer, manufacturer and the consumer, but also between researchers and designers etc, involved in different fields of research. As an example he pointed out that good communication was needed between ventilation engineers, air quality and indoor air quality hygienists.

He emphasised that many problematic buildings may take many years to make healthy, so since the technology exists why not design and build them right in the first place. The human element is missing from many equations. The building might well function perfectly well before occupation, but what happens afterwards? To this end several new ventilation design principles, such as DCV and displacement ventilation are being installed. But there are still many unanswered questions, such as should we calculate or test, is the model really reliable? David also pointed out that verification of data was a vital element in research both now and in the future, and emphasised the importance of the AIVC's numerical database in this task. Research is becoming more focused on ventilation effectiveness, not just air changes per hour. The real world should be placed into some kind of perspective, definitions often prove elusive, and experience with real buildings is limited. He ended by saying that conferences such as this one simply go to show us that the major challenges still exit.

International Energy Agency

Air Infiltration and Ventilation Centre

12th AIVC Conference

Air Movement and Ventilation Control within Buildings

Venue: Château Laurier, Ottawa, Canada

Date: Tuesday 24th to Friday 27th September 1991

Co Sponsors:

IEA Energy Conservation in Buildings and Community Systems

Annex 18 "Demand Controlled Ventilating Systems"

Annex 20 "Air Flow Patterns within Buildings"

First Announcement and Call for Papers

Intensive analysis on the characteristics and control of air flow into and within buildings is currently taking place. The purpose of this conference is to review progress in this field with special emphasis on applicability for ventilation design, optimisation and diagnostic analysis. Topics cover:

- Theory of Flow Mechanisms
- Calculation Techniques
- Measurement Methods
- Validation Methods and Data
- Application of Air Flow Simulation in Design
- Demand Controlled Ventilation Systems and Strategies

Abstracts of proposed papers on these topics are welcome and should be forwarded to Martin Liddament at the AIVC by January 31st 1991. Abstracts will be reviewed by March 1991 and accepted papers will be required by July 1991. The conference will take the form of both author presentations and displays, with the final distribution being determined at review. Authors are welcome, however, to state their preference. Proposals from non AIVC countries are welcome.

Forward abstracts to:

Air Infiltration and Ventilation Centre

University of Warwick Science Park

Barclays Venture Centre

Sir William Lyons Road

Coventry CV4 7EZ

Great Britain Tel +44(0)203 692050 Fax +44(0)203 416306

Annex 23 Multizone Air Flow Modelling - A New IEA Annex

A Report by Martin Liddament, Head, Air Infiltration and Ventilation Centre

As improvements to the thermal efficiency of buildings continue, ventilation and air flow will eventually become the dominant source of heat or cooling loss. Furthermore, in addition to direct energy considerations, the pattern and magnitude of air flow also have important consequences in relation to indoor air quality and comfort. Thus modern design must take into account the provision and distribution of air. However, the diversity of building type, combined with uncertainties over the interaction of behaviour of individual components or systems, means that faults in design can easily occur. Problems including inappropriate tightness of the building shell, duct leakage and insufficient consideration of the internal flow network will all contribute to increased energy use and/or unhealthy buildings. While standards and guidelines addressing such needs would be helpful, very few exist. Even when standards do cover the performance of individual components, the net benefit can be lost by poor building construction or incompatibility between components. It is possibly lack of knowledge in this area, combined with an obvious concern that inadequate ventilation will result in potentially serious indoor air quality problems, that has done much to limit success in controlling the indoor environment and in achieving substantial further reductions in energy use. A clear understanding of the relationships between ventilation rates, air flow patterns and consequential energy and environmental impact would do much to improve the potential for energy efficiency in buildings.

It is this background that motivates much of the air flow related research of the International Energy Agency's Executive Committee on Energy Conservation in Buildings and Community Systems. While considerable effort is being devoted to ensure the full transfer of existing knowledge to both designers and regulators, many uncertainties still exist and hence further work is still needed. One such area relates to numerical models which are not only essential as design tools but are also invaluable in providing an insight into the interaction of different components within a system. Unfortunately, however, although air flow related models have become more widely available over recent years, their reliability and range of applicability have not been adequately evaluated and hence there has to be a doubt over the reliability of results. These types of models are also generally difficult to use, with the result that their application is largely restricted to specialists rather than being available to the general practitioner. In addition, much is often left to the judgment and skills of the user to interpret or understand the results.

IEA Annex 23 has been established in order to attempt to resolve these difficulties in relation to multizone air flow modelling. These models are used to evaluate the air flow between individual rooms or zones as well as the rate of inflow and outflow of air from buildings. This approach is especially important for evaluating the adequacy of ventilation, predicting pollutant transport and evaluating airborne heat transfer between zones. Such models therfore have vital applications in both energy and air quality related analysis.

Initially multizone simulation techniques were confined to mainframe computer systems, Now, however, they are available for operation on "PC" based systems on which quite complex networks can be investigated. This has resulted in wider availability but many still tend to lack "user friendliness". Other problems include lack of suitable input data (eg leakage characteristics of openings and wind pressure values) and inadequate validation through lack of sufficient supporting measurement data. The purpose of Annex 23 is to address all of these points in order to provide a method which may be reliably used for both research and design applications. The annex is divided into three subtasks, these being:-

- Subtask 1: Model Development with User Friendly Front-End
- Subtask 2: Data Acquisition for Model Evaluation
- Subtask 3: Model Evaluation

Subtask 1 is seen as an extension to the COMIS initiative (AIVC Technical Note 29) in which an "Intelligent Simulation Environment" (ISE) is to be developed to assist a user in setting model parameters and developing a flow network. Additional tasks include the incorporation of pollutant transport and demonstrating the coupling of a multizone model with a thermal building simulation model. An outline of the ISE is illustrated in Figure 1. Its essential feature is to couple the user to a model via a series of graphic data input screens. Data is then provided by the user or taken from internal databases. An expert system is also available in order to assist the user in selecting the best information. This task therefore represents an attempt to provide the user with the necessary knowledge and tools to use a model. Essential to this subtask is also the selection or development of an appropriate algorithm for the simulation of multizone air flow.

Modules for incorporation in this algorithm include flow through large openings, single sided flow, and crack flow.

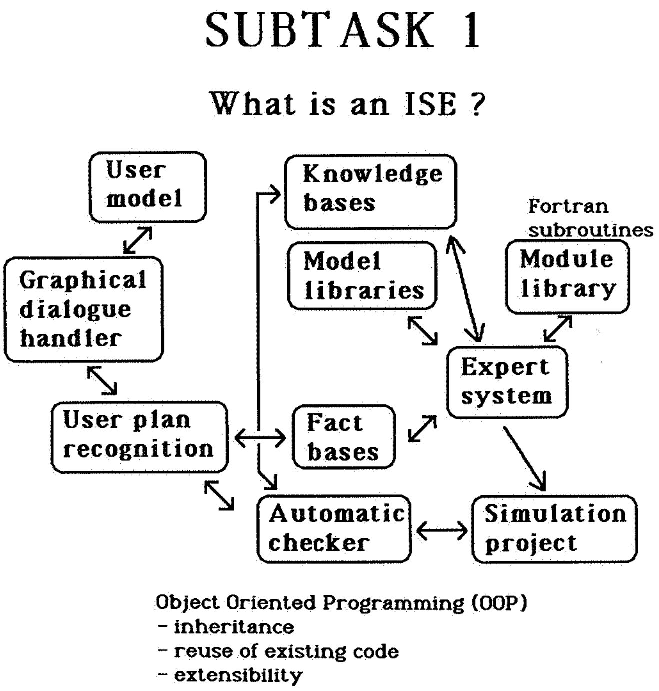


Figure 1: Outline of ISE

Subtask 2 is fundamental for the independent evaluation of multizone models. Its objectives are to identify input requirements, assess the quality or accuracy needed for input data and to obtain appropriate datasets based on these needs. Much data are already available but do not necessarily reflect all the requirements of existing models. Where existing data are used, emphasis will be placed on quality assessment, dealing with missing data items, establishing rules for any interpolation requirements and carefully discriminating between actual measured data and derived values. To support existing data, an extensive measurement programme is envisaged in which clearly defined examples will be selected for analysis. In providing new datasets, emphasis will be directed at clearly defining the objectives of each measurement in the context of evaluation needs, standardising the format of data collection and standardising procedures for estimating errors. It is intended that the experimental programme should include measurements on isolated systems within the laboratory, the use of test cells, field measurements on "simple" buildings of different constructional techniques and field measurements on more complex buildings such as multi-storey office buildings. It is also intended that as wide a range of climatic and exposure conditions as possible be applied. A particular advantage of fulfilling this task by international collaboration is that as well as the sharing of cost, this type of approach enables the widest range of construction, ventilation and climatic conditions to be included within the study.

Subtask 3 is concerned with establishing a protocol for model evaluation. This would be applicable to the evaluation of any multizone technique and hence has applications outside the existing annex by providing usable datasets for general validation purposes. It hence has important value within the AIVC's own Numerical Database for application in future validation studies. The goals of this subtask are to ensure that the model performs according to benchmark criteria, to determine the domain of application and, by means of feedback from the results, improve model performance. Still to be established are the criteria against which a model will be judged. Also, when comparing a model against measurement data, the deviation of the measurement from the physical quantity being measured must be understood. These aspects will therefore form an early part of the subtask. Some of these issues are also currently being addressed by IEA Annex 21 "Thermal Modelling" and consequently it is hoped that valuable input for the benefit of this subtask will be obtained from this particular Annex.

The first formal meeting to discuss the necessary tasks and to set a schedule for undertaking and completing this work was hosted by France in October. An approximate timescale of 12-18 months preparation phase and 24-30 months operational phase was established within an overall 3.5 year time frame. During the forthcoming 6 month period, an operating agent and subtask leaders are to be appointed. It is then hoped that a full start on the project can begin early next year. Initial tasks include establishing the availability of existing algorithms (eg COMIS) and determining the need for additional codes (eg for incorporating special flow mechanisms, pollutant and thermal transport etc). This would take the form of a state of the art review and a survey of public domain simulation codes. Once a general multizone algorithm incorporating the desired features has been compiled, then work can commence on adding the user interface or "Intelligent Simulation Environment". The proposed knowledge or input database will, in part, be based on the comprehensive numerical database being compiled by the AIVC (Air Infiltration Review, Vol. 11, No. 3, June 1990, pp7-8).

This new annex will also draw upon the results of IEA Annex 20 "Air Flow Within Buildings" which has devoted an entire subtask to developing and analysing techniques for the measurement of multizone air flow. These validated techniques will form the basis of future experimental work within Annex 23. In addition, data sets derived from multizone measurements in Annex 20 will provide initial input to the validation exercise.

Organisations interested in contributing to this Annex should contact their IEA Executive Committee Member or, alternatively, contact Martin Liddament at the AIVC who would be pleased to provide further information. The next meeting of this group will take place in April 1991.

Infiltration in Norwegian Houses

Jørn Brunsell, MSc. and Sverre Fossdal, Dr. Ing.

Norwegian Building Research Institute

Abstract

Air infiltration in Norwegian buildings has been an unknown parameter. This paper is based on results from measurements in nine different buildings in Norway. The measured parameters have been:

- infiltration
- wind velocity and direction
- pressure differences across the building envelope
- air humidity and temperatures on the inside and outside of the building

The infiltration has been measured continuously with tracer gas using the constant concentration method. In addition air tightness measurements and thermography have been carried out to establish the dimensions and the locations of the major leaks. In buildings with mechanical ventilation systems, the flow rate through the inlets and outlets have been measured.

The results from the measurements show a higher infiltration rate than expected. The two houses described in this paper show, without occupancy, an infiltration rate of 0,7 ach.

1.0 Background

The energy consumption in buildings consists of consumption to light, machinery, hot water, heating and ventilation.

The demand of energy to heating and ventilation can be divided into transmission loss, controlled ventilation and infiltration.

The magnitude of the infiltration loss has in many ways been unknown until now. Even if there over the recent years in many countries have been done substantial work to investigate the air infiltration in buildings the results can not be transferred from one country to another. The extent of the air infiltration depends on the different countries' regulations to air tightness of buildings, type of building construction, etc.

In Norway it has been common to calculate the infiltration loss to 0,3 air changes per hour (average) when building heat demands have been estimated.

To be able to build more energy efficient buildings it is essential to know the dimensions of the air infiltration and decide what should be done to reduce it.

By measurements of the air change rate in buildings without running the ventilation system the air infiltration can be stated.

2.0 Measurement Techniques

By using tracer gas measurement techniques the infiltration can be found. There are three different techniques in use.

- concentration decay method
- constant emission rate method
- constant concentration method

In this project we have used the constant concentration method.

- high accuracy
- real time

The disadvantage is

- expensive equipment
- time consuming setting up

The tracer gas used is sulphur hexafluoride SF_6 and a constant gas concentration of 5 ppm has been established in the building.

The tracer gas mass balance equation can be presented as

$$V\frac{dC}{dt} = Q\,[C_e - C_{(t)}] + F$$

Where

V = Effective volume of enclosure, m^3

Q = Specific air flow rate through enclosure, $m^3\,s^{-1}$

C_e = External concentration of tracer gas

$C_{(t)}$ = Internal concentration of tracer gas

F = Production rate of tracer by all sources within the enclosure.

The solution of the equation based on zero concentration of tracer gas at start will be

$$C_{(t)} = \frac{F}{Q}(1 - e^{-Nt})$$

Where

N = Q/V Air change rate per unit time

If N remains constant, a finite time is required for the tracer concentration to reach equilibrium (determined by $(1-e^{Nt})$. Once the concentration has reached equilibrium the air flow rate is given by

$$Q=\frac{F(t)}{C}$$

Where

C = constant tracer concentration in the building (5 ppm)

$F_{(t)}$ = Production rate of tracer gas at time t.

The air change rate is proportional to the production rate of tracer gas.

The measuring equipment used in this report can do measurement in ten different rooms at the same time with an accuracy of ±10 %. The measurements are controlled by a computer and parallel wind pressure differences, temperatures, wind speed and direction and relative humidity be measured. The equipment calculates the air change rate and collects all analog data every three minutes. Any possible connections between the analog data and the change in air change rate can be found.

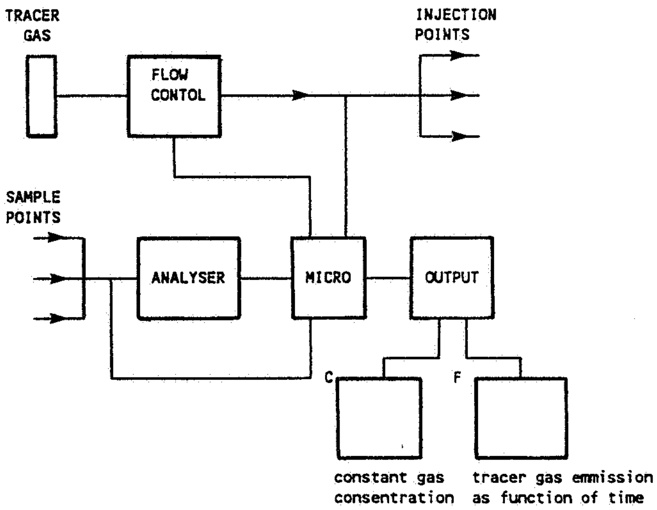


Figure 2.1 Schematic of constant concentration equipment

3.0 Results

From the nine buildings that are measured, detailed results are shown from two of them. One eight storey office building and one single family house.

3.1 Office Building

The office building is an eight storey building with brick walls and concrete floors. There is a lift and a stairway that forms a shaft in the middle of the building. We measured one separate part of the seventh floor which was divided into seven zones, one for each room, (See fig. 3.1.1). Dosing and sampling were done in each zone. In addition the gas concentration in the corridor was measured. The building has a balanced ventilation system with inlets and outlets in each room. The volume flow for each inlet and outlet were measured.

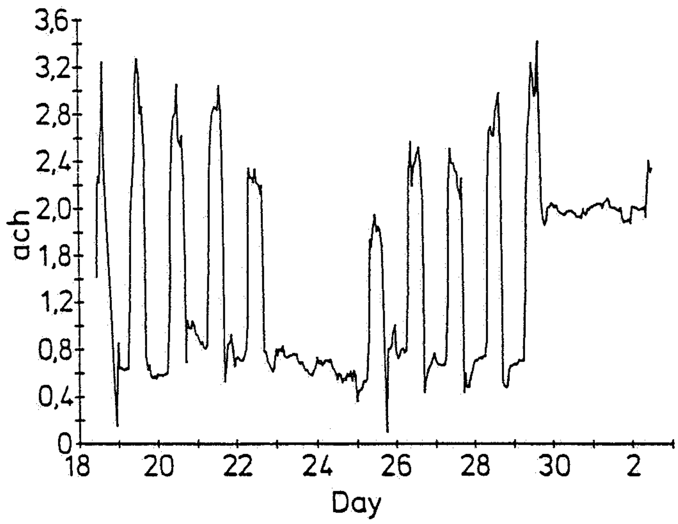


Figure 3.1.1 The average ventilation rate measured in the office building on the seventh floor. The measurement was carried out for a period of two weeks. During the first week the internal doors were closed and during the second week all internal doors were kept open.

All the offices were occupied during daytime on weekdays but not on Saturdays and Sundays. The ventilation system was turned on at seven a.m. and shut off at four p.m. on weekdays. Usually the ventilation system is off during the weekends, but during the last weekend it was running.

From the measurements we can conclude with the following key figures:

	Min	Average	Max
	ach	ach	ach
Total air change rate, daytime	1.9	2.8	3.4
Infiltration, vent. syst. running	0.6	0.7	0.8
Ventilation through windows	0.0	0.8	1.3
Ventilation through ducts	1.3	1.3	1.3
Infiltration, vent. syst. off	0.6	0.7	1.0

3.1.1 Discussions

There were big differences from one zone to another in airing through the windows. The total air change rate rise, in one zone, 6 ach in average because of airing through windows.

The ventilation system was running only one weekend without any occupancy. For that period we have studied the influence of the weather conditions on the air change rate, which in this case is the infiltration rate. During this period the wind velocity was low (the average was about 3 m/s). The variations are mostly due to the difference in the outdoor and indoor temperature. The indoor air temperature was stable about 23°C and the outdoor temperature varied from -3 to +5 ° C. This caused the change in the infiltration from 0.8 ach to 0.55 ach.

The wind velocity was not measured continuously for this period. However, we have information about the wind velocity 4 times a day and also continuous measurements of the pressure differences across the building envelope. From this we can see a slight rise in the infiltration rate when the wind increases, but significant figures can not be stated for this building.

3.2 Single Family House

3.2.1 Air Change Rate Measurements

This 260 m^2 house, which is from 1973, consists of two stories. It has walls of wood frame construction, natural ventilation with four outlets, one from each wetroom and eight inlets on the first floor. The size of each outlet was about 50 cm^2 when it was open. The inlets were shut during the measurements.

Gas was injected in seven zones and the concentration was sampled in 10 zones. The measurements were carried out for a period of two weeks where the results from the first week are infested with some uncertainties. During the first 5 days of the last week the occupants were not at home. The 4 outlets were open 2 days of this period.

When the occupants were not at home we can observe the immediate reaction in the infiltration rate caused by changes in the weather conditions, (See fig. 3.2.1).

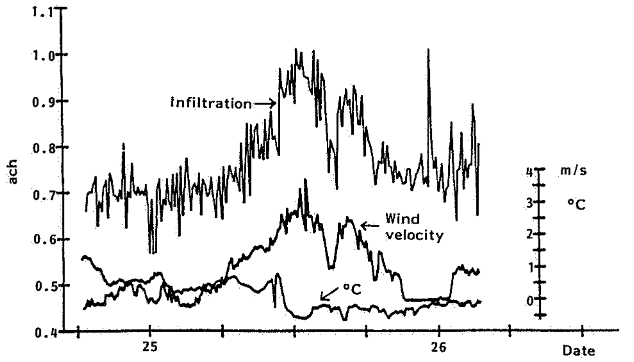


Figure 3.2.1 The influence of the wind velocity on the infiltration rate (the whole house). Inlets and outlets were shut and the occupants came home late in the evening the 25th.

From the measurements we can conclude with the following key figures for the single family house:

	Min	Average	Max
	ach	ach	ach
With occupancy:			
Total air change rate 4 outlets open (200 cm^2)	0.7	0.8	1.3
Without occupancy:			
Total air change rate 4 outlets open (200 cm^2)	0.7	0.8	1.1
Infiltration (no vents open)	0.6	0.7	1.0

3.2.2 Air Tightness Measurements

Air tightness measurement was carried out and the n_{50} - value was found to be 6.9 ach. The Norwegian building code requires for new detached houses today the n_{50} - value to be less than 4.0 ach.

3.2.3 Discussion

During the first 10 days all the ventilation inlets and outlets were shut. The measured air change value for this period is the same as the infiltration rate. In average the figure was 0.7 ach which is more than needed for ventilation pruposes. The outside temperature was higher than normal and the wind velocity was lower.

4.0 Air Change Rate Measurements in Seven Buildings

The other seven buildings differ from the two reported here in size and form.

Type of building	Year of constr.	No of storeys	Measured storey	Inf. rate v.sys. off	Tightness n_{50}
Office building	1943	3	All	0.8	-
Office building	1965	4	1st floor	0.7	-
Office building	1985	3	1st floor	0.4	-
Row-house	1960	2	All	0.7	7.8
Single family house	1982	3	All	0.2	2.2
Apartment building	1960	2	2nd floor	0.5	7.6
Kindergarten	1968	1	1st floor	0.5	11.6

The infiltration rate depends on several parameters. The results presented above are average values when the ventilation systems were off. If the building had natural ventilation system the inlets and outlets were shut and no occupants were in the building.

5.0 Conclusions

Both the buildings reported in this paper had a higher infiltration rate than expected. In both cases the figure in average, without occupancy, was about 0.7 ach. The office building has a balanced ventilation system which means that all leaks represent an energy loss.

The single family house has a natural ventilation system with 4 outlets and 8 inlets. The air change rate without the vents open (infiltration rate) is more than needed to ventilate the building in average. the outlets in the bathrooms are recommended to be kept open for humidity control in these rooms. the major leaks found by thermography, are recommended to be sealed in order to make the houseowner able to control the air change rate better and to reduce the energy loss.

Eight of the nine buildings had a higher infiltration rate than needed for ventilation purposes, therefore it is of big importance to make tighter buildings in order to reduce energy consumption and to get better indoor climate.

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Acknowledgements

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This paper was presented at the symposium "Building Physics in Nordic Countries", held in Trondheim, Norway, 20-22 August 1990.

International CIB W67 Symposium

Energy Moisture and Climate in Buildings

September 3 - 6, 1990, Rotterdam

by James Piggins, Project Scientist, Air Infiltration and Ventilation Centre

Introduction

Rotterdam in September was the setting for the first CIB symposium integrating the three subject areas of energy, moisture and climate in buildings. Designed to bring together experts from many backgrounds, the symposium was organised under the auspices of CIB Working Commission: W67 - Energy Conservation in the Built Environment, with the active participation of CIB Working Commissions: W40 - Heat and Moisture Transfer, and W17 - Heating and Climatisation.

Opening Session

According to Eltjo Tammes, President of the International Symposium Committee, the major goal of the Working commissions and hence of the symposium was to optimise building practices via the processes of standardisation, quality assessment and regulation. Thus he saw a strong link with troubleshooting and the need for international standards. The background to the symposium was the changing perception of the moisture problem, the early perceived importance of interstitial condensation in buildings in the late 60's, being considered less important towards the mid 70's. In the early 80's however moisture damage due to increased energy conservation methods was becoming apparent, hence the new emphasis on an integrated approach to moisture and energy and the need for this symposium.

Building Regulations

The Symposium was organised into four seminars and three technical sessions with a parallel poster session running during the whole event. The first seminar "Principle Features of Building Regulations", was introduced with a keynote address from Mrs M Andersson, of Byggstandardiseringen, in Sweden. She explained how good standards are preferable to exact regulations; legislation is simplified, trade barriers reduced, and international standards become possible. Additional advantages of standards over legislation are that changes can be made in standards easier than regulations and most technical staff are familiar with the use of standards. Concerning the forthcoming European standards, the aim is to speed up unification, thus matters such as safety, health and environment will be dealt with by specific legislation but technical specifications will be covered by the new standards. Implementation of these standards will require the total replacement of national standards but they will only be voluntary until referred to in legislation and made mandatory. In conclusion Mrs Andersson emphasised that standards should encourage development not strangle it, and should therefore specify performance requirements rather than methods.

Of the eight papers on Building Regulations published in the proceedings three were presented. Mr J M Evans of the Research Group Habitat & Energy, Argentina, spoke about the problems of implementing standards in developing countries where the building stock is often of very variable quality and the available technology and materials limited. The development processes leading to a new ASHRAE standard for energy efficient low rise residential buildings was described by Mr M F McBride, of Owens-Corning Fiberglass, USA. The third paper presented by Mr C M van den Hoff from the Netherlands concerned the link between the built environment and the law, concentrating on the motivation for change in new buildings.

Ventilation and Heating

The second seminar concerned strategies for ventilating and heating buildings. This session was opened with a keynote address from Prof K Gertis from the University of Stuttgart also Director Fraunhofer Institut Stuttgart, Germany. He took the theme that building solutions depend on climate. In particular he cited two different approaches, one for cooler northern climates - to minimise heat losses and one for warmer more southerly climates - to maximise solar gains. He stated the pitfalls of inappropriate technology whereby passive solar houses can have too high summer internal temperatures and in winter can have greater energy losses. For more northern climates he recommended the use of more conventional structures with better insulation, more efficient and better sized boilers and improved controls. He felt that the building sector can easily contribute to a reduction in greenhouse gasses. In particular stating that the increased proportion of heat losses due to ventilation in well insulated dwellings will require the use of more mechanical ventilation systems with heat recovery.

Mr G F M Brouwers from The Netherlands described a combined heating and ventilating system called Energon (Figure 1) which passes ventilation air through floor cavities thus using the thermal mass of the building to reduce energy consumption. Mr K Ishida of Sekisui House Co Ltd, Japan, presented a simulation program for room air, temperature, humidity and heat load taking into account moisture absorption in building elements. Results were quoted as being good but had not been compared with real measurements.

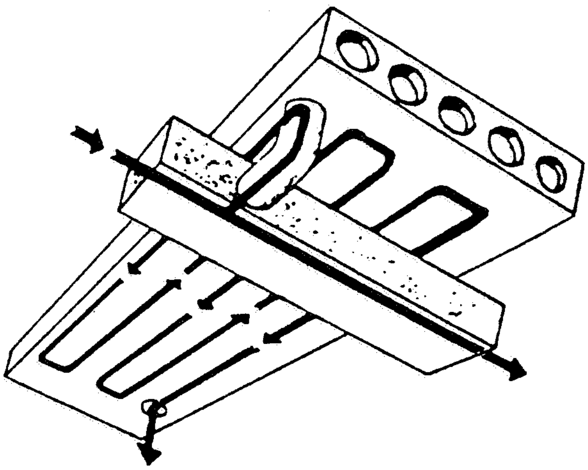


Figure 1. The Energon system

An interesting paper on the problems of modern window design was presented by Prof E Panzhauser, of the Technische Universitat Wien in Austria. This highlighted the fact that 80% of Austrian windows are of the tilt and turn type. These are either fully open or closed giving very little control over ventilation rates. He thus recommended that windows with continuously variable openings should be used (Figure 2). Following his paper, questions were asked on the use of trickle vents which he felt were inefficient, unless two were installed in a room at differing heights.

Mr N Bergsoe of the Danish Building Research Institute, described the use of passive sampling techniques to measure ventilation rates and humidities. A questionnaire was also filled in by the occupants during the setting up of the experiment. He has investigated whole house ventilation rates and the ventilation rates of three zones as well as interzonal airflow rates. Organic vapors are also monitored using passive samplers. Relative humidity was measured using the unusual method of exposing a wood block of known weight to room air for the period of the experiment. The passive samplers and the block were then returned for analysis by the residents in postage paid bags. The weight of the block when returned plus a single temperature measurement during setting up, give an indication of the relative humidity during the exposure period. Interestingly all houses returned similar values for relative humidity.

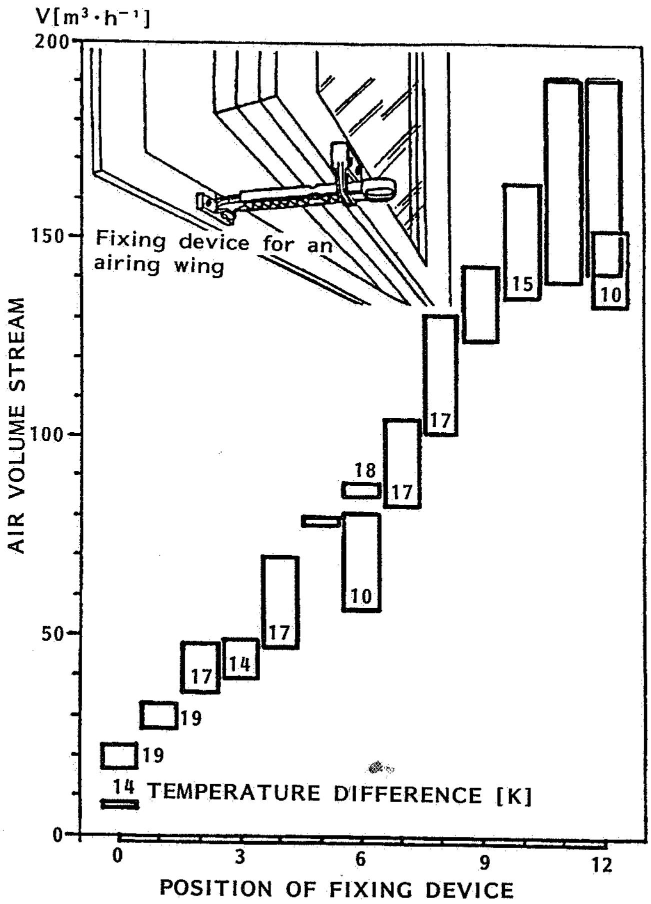


Figure 2. Air volume stream through a modified tilt & turn window depending on the position of the added fixing device.

The cooling of offices using various different ventilation strategies including evaporative cooling and night-time ventilation was detailed by Mr J R Millet of the Centre Scientifique et Technique du Batiment in France. This approach is designed to avoid the use of expensive and potentially environmentally damaging refrigeration plant in commercial buildings. The conclusions were that an evaporative cooling system using 4 ach/h would be sufficient in northern France, with 7 ach/h being needed but still practical in warmer regions further south. In Mediterranean climates in southern France however 12 ach/h would be required which would probably be impractical. This paper thus returned to the theme of the keynote address for this session that building solutions relate to climate.

A further ten papers on ventilation and heating have been published in the proceedings. These include papers on indoor climate, energy efficiency, building materials, building simulations and future developments in building technology.

Moisture Problems in Buildings

Seminar 3 and Technical Session I both focused on moisture problems in buildings, seminar 3 looking in particular at "Surface Condensation & Mould Growth". The main topic of the published papers in the seminar was the effects of thermal bridges. Other papers concerned the effects of different internal finishes and building materials, surface effects and boundary conditions, renovation techniques, the health effects of airborne mycotoxins and the prediction of indoor air humidity.

Technical session I contained 45 published papers, which concentrated on moisture transport within the building and its components. The hygroscopic properties of building materials were discussed in some length, as well as the hygrothermal properties of some building structures. Methods for modelling heat, air and moisture transport within a building also received much attention. Thus whereas seminar 3 detailed some of the problems and possible solutions, the technical session concentrated on the mechanisms involved.

Building Energy Control Systems

Energy distribution by means of physical or automatic control was covered by seminar 4 "Building Energy Management and Control Systems". Papers presented included one from Mr W Braun of Geilinger Ltd, Switzerland, describing the use of a displacement ventilation system to 'free cool' a building at night, thus avoiding more expensive refrigeration systems. This approach combined with a highly energy efficient building envelope has produced a much reduced energy cost for the building.

The use of the correct control philosophy was emphasised in a paper presented by Mrs P Laitila of the Technical Research Centre of Finland. This paper concerned the comparison of two different control systems and the control variable to be used. Cascade control of room temperature was considered where inlet air temperature or inlet air volume flow rate is the control variable (depending on the type of air conditioning system) and direct room air temperature control when the reheating coil valve position is the control variable. Cascade control was found to be the best system, since it can compensate for disturbances such as changes in inlet air temperature before they affect the room temperature. Whether it is better to measure room air temperature or exhaust air temperature was not determined as perfect mixing of the space was assumed. However it was stated that in the case of multiple volumes being controlled from one measurement it is better to measure the exhaust air temperature.

Other papers presented in this session looked at building energy management systems and window design in hot dry climates. The remaining published papers in this session include such subjects as nocturnal cooling of the building structure, the effects of ventilation in unoccupied spaces on air conditioning load, the monitoring of energy usage in buildings, and the effect of various different heating and air conditioning regimes.

Natural and Mechanical Ventilation

Technical session II was opened with a paper from Mr J Simonnot of AERECO in France. This gave details of a natural humidity-controlled ventilation system designed to improve ventilation in dwellings in existing apartment blocks where ventilation ducts to the roof are already present (Figure 3). This system uses humidity controlled inlets and outlets which vary the amount of airflow automatically according to the internal humidity of the room. These vents utilise nylon filaments whose length varies according to humidity thus opening or closing the vents as required. It was shown that these vents vary flow rates according to the number of occupants and therefore the amount of moisture generation. The ventilation rate was kept fairly constant for a given humidity level regardless of outside temperature, preventing excessive energy wasting ventilation due to increased stack effect in colder weathers.

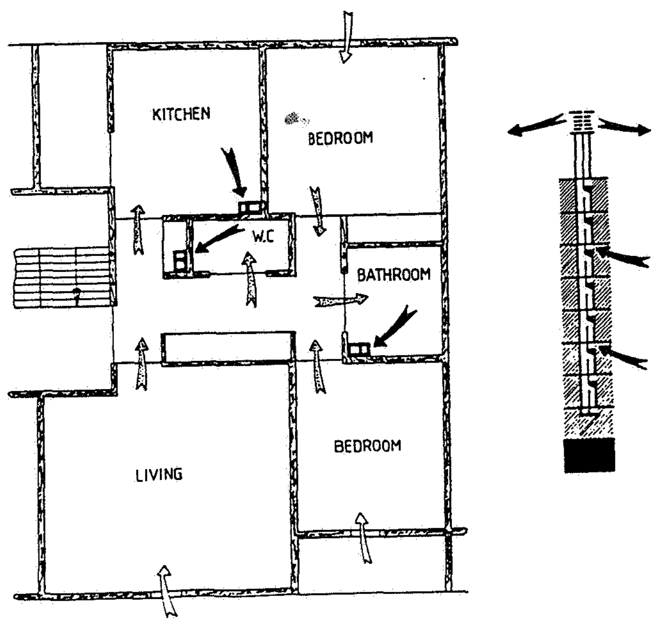


Figure 3. The principle of humidity controlled air circulation & a common ventilation duct with individual connections at each storey of a block of flats.

Mr C W J Cox of the Department of Indoor Environment in The Netherlands, presented a paper on a field study of displacement ventilation in an office. Measurements of temperature efficiency, air change efficiency and ventilation efficiency were carried out. Some improvements were found compared to a more conventional dilution ventilation system. Interestingly temperature distribution in the room was found only to be dependent on the supply air temperature; other factors such as internal heat load, outdoor temperature, insolation, exhaust flow rate or people moving around in the space had no discernible effect. Air change efficiency was very dependent on the balance between supply and exhaust airflow rates; the better balanced the system the better the efficiency. In particular it was found that floor level exfiltration caused a marked reduction in air change efficiency.

Other papers presented in this session were the numerical simulation of thermal convection in a room with buoyancy driven natural ventilation was described by Mr J Tsumi of Tohwa University, Japan, this compared the results of a simulation with results from a laboratory model. The evaluation of multi-zone airflows using a random search technique was presented by Mr E H Tumbuan of Delft University of Technology in the Netherlands. Mr L J A M Hendriksen of the Netherlands Organisation for Applied Scientific Research proposed a new method of rating the average annual performance of small air-to-air heat recovery units. The main problem being addressed by this method is how to predict the average annual efficiency of a heat recovery unit in average operating conditions. The calculation method was described and the necessary measurements required for its implementation detailed. Finally a humidity controlled ducted ventilation system was presented by Mr K Lethermann from the University of Manchester in the UK.

The remaining eleven papers in this area published in the proceedings cover such topics as: permeability of dwellings, heat storage for ventilation, wind pressure distributions, ventilation models and calculation procedures, demand controlled ventilation, expert systems for the design of ventilation systems, ventilation and heat loss, and humidity controlled ventilation systems.

Energy Conservation Measures

The final session of the symposium was Technical Session III concerning energy conservation measures. Mr C E Hagentoft of Lund University in Sweden, presented some useful investigations into heat loss through the building slab. The algorithms he has developed allow heat losses to be estimated for transient temperatures i.e. yearly cycles; they also allow assessment of the peak effects.

Prof H Hens of Katholieke Universiteit Leuven in Belgium demonstrated the importance of details in workmanship, method of construction and design when building well insulated cavity walls. In particular he highlighted the increased heat losses caused by convection currents round incorrectly fitted partial fill insulation. In some cases these structures have U-values 3 times their design values. Summer condensation occurring within the cavity on the inner leaf also contributes to heat losses by evaporating in winter producing a significant latent heat loss. This can increase the U-value of a structure by 90% during the evaporative process. Additional heat losses can also occur due to cold bridging through lintels also leading to condensation problems. Prof Hens recommends that cavity walls be built by constructing the inner leaf, installing the windows, then insulating the whole structure before adding the outer leaf, thus ensuring no cold bridges and minimal convective heat transfer within the cavity.

Mr P Jones of the University of Wales in the UK, continued Prof Hens's theme of how poor workmanship and insufficient care with design can effect structural heat losses, in this case highlighting the problems of commercial and small industrial buildings. Interestingly the problems are broadly similar to that of residential buildings with cold bridging and missing insulation being the main faults found in a series of infra-red thermography surveys carried out on industrial buildings in Wales.

Mr R Oman of the Royal Institute of Technology in Sweden, presented a case study of polyurethane insulated single family houses using new building components. These lightweight structures, although extremely energy efficient when combined with exhaust air heat pumps to provide space heating and hot water, suffer from one fundamental design flaw. This is due to the nature of the lightweight structure which allowed a high degree of sound transmission, people outside the house being able to hear conversations inside the house, thus necessitating the building of an outer skin on some walls to provide better sound insulation. These houses were thus another example of how design which concentrates too much on energy efficiency can cause problems in other areas.

Symposium Summary

At the end of the symposium a summary session was used to pull together the three subject areas covered. Comments were invited from three observers as to the symposium itself. This produced significant criticism of the communication process between the researcher and the building industry. The lack of involvement of experts in building design was highlighted, along with the interaction between experts in the three areas covered by the symposium. It was felt that little work was carried out by multidisciplinary teams and that many of the papers had thus highlighted the problems of concentrating too much on one subject. A typical example of this must be the large number of papers concerning condensation and energy loss caused by thermal bridging. It was felt that insufficient work is done to disseminate these results and that most papers do not emphasise the practical implications of the work done. This is obviously an area we as experts need to concentrate on.

The major problems are obvious. The work done must be channelled into appropriate standards, which will provide a communication medium and incentives to architects and developers to improve the quality of building design and implementation. By looking more at the building as a total system many current problems can be avoided. Excessive ventilation was not viewed as the answer to moisture problems: prevention is better than cure! Demand controlled ventilation however, in the form of humidity controlled systems is gaining acceptance in new and retrofit situations, as new technological solutions appear in the market place. Ventilation with heat recovery, will be a growth area in newer low energy residential buildings. Properly designed ventilation systems in commercial buildings will tend to replace (wholly or partially), expensive environmentally damaging refrigeration plants and provide a nett energy saving as a result. Thus ventilation in buildings still has a vital role to play in the energy saving equation, but the fundamental design of the building envelope must be correct. Correct ventilation is a design tool not a cure-all. This symposium highlighted these problems; hopefully it has contributed to preventing them in the future.

Abstracts of the ventilation related papers mentioned in this article may be found in the latest copy of AIVC Recent Additions to AIRBASE.

Review

Indoor Air Pollution Control

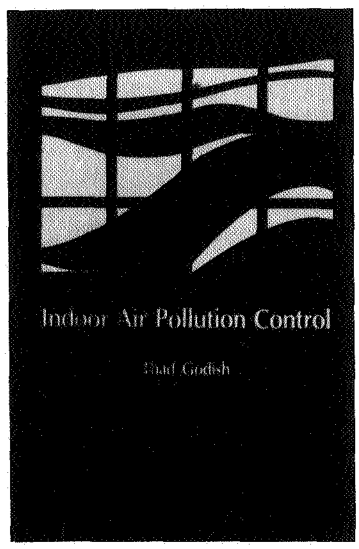
by Thad Godish

Published by Lewis Publishers, Michigan, USA
first published 1989, second printing 1990

AIRBASE #NO 4271

In eight sections:-

- 1. Problem Definition
- 2. Source Control - Inorganic Contaminants
- 3. Source Control - Organic Contaminants
- 4. Source Control - Biogenic Particles
- 5. Ventilation for Contaminant Control
- 6. Air Cleaning
- 7. Policy and Regulatory Considerations
- 8. Air Quality Diagnostics
- 9. Mitigation Practice



This book has been written primarily as a reference work. It contains an overview or definition of the problem and expanded discussions of source control measures for specific contaminants such as asbestos, combustion-generated pollutants, radon, formaldehyde, volatile organic compounds, pesticides, and biogenic particles. It also reviews public policy and regulatory issues associated with the problem.

Beyond these reference aspects of the book, the author expands the utility of his work by the inclusion of chapters dedicated to problem solving. Chapter 8 focuses on air quality diagnostics. It is designed to assist readers in identifying specific indoor air contamination problems in residences and public buildings. Chapter 9 describes suggested mitigation practices on a case history basis. Chapters 8 and 9 are practical guides to identifying and solving real-world problems. As such, they complement the theory and principles, the primary focus or the reference part of the book.

The book is intended for a variety of audiences, including public health and environmental professionals, industrial hygienists, consultants, architects, and academics. It may prove particularly valuable to physicians who wish to become familiar with indoor air quality problems experienced by patients and to include indoor air quality principles and applications in clinical practice.

Review

Design and Protocol for Monitoring Indoor Air Quality

Edited by N L Nagda and J P Harper

Published by American Society for Testing and Materials 1989

AIRBASE #NO 4264

This publication contains papers presented at the Symposium on Design and Protocol for Monitoring Indoor Air Quality, which was held in Cincinnati, Ohio on 26-29 April 1987. The symposium was sponsored by ASTM Committee D-22 on Sampling and Analysis of Atmospheres in cooperation with the Air Pollution Control Association and the American Industrial Hygiene Association. Niren L Nagda was the symposium chairman and Jerome P Harper and James E Woods presided as symposium co-chairmen.

Contents are as follows:-

- Comparison of effects of ventilation, filtration, and outdoor air on indoor air at telephone office buildings: a case study, by C J Wechsler, H C Shields, S P Kelty, L A Psota-Kelty, and J D Sinclair
- Investigation of a Washington, D C office building, by A K Persily, W A Turner, H A Burge and R A Grot
- Factors that may affect the results of indoor air quality studies in large office buildings, by O Seppanen and J A Jaakola
- Project and problem definition in building air quality investigations, by P F Allard
- Indoor air quality diagnostics: Qualitative and Quantitive procedures to improve environmental conditions, by J E Woods, P R Morey, and D R Rask
- Indoor air quality and ventilation measurements in energy-efficient California State office buildings, by H Levin and T J Phillips
- Workshop: data collection aspects of building investigations, by W A Turner, H A Burge and A K Persily

Residential Buildings

- Case study: multipollutant indoor air quality study of 300 homes in Kingston/Harriman, Tennessee, by A R Hawthorne, C S Dudney, R L Tyndall, T Vo-Dinh, M A Cohen, J D Spengler and J P Harper
- Experimental design and protocols for research at GEOMET's test houses: a case study, by M D Koontz and N L Nagda
- Selected protocols for conducting field surveys of residential indoor air pollution due to combustion-related sources, by G W Traynor
- Design of a total human environmental exposure study (THEES) for benzo(a)pyrene in New Jersey: the microenvironmental survey, by R Harkov, J Waldman, P J lioy, A Greenberg and F Darack
- Prediction of long-term exposure to indoor air pollutants using short-term measurements, by J H White
- Workshop: Designing indoor air quality survey studies, by M Kollander, R Whitmore, L Wallace and F C Brenner
- Workshop: development of questionnaires and survey instruments, by M D Lebowitz, J J Quackenboss, M L Soczek, S D Colome, and P J Lioy

Instrumentation and Methods

- Workshop: instrumentation and methods for measurement of indoor air quality and related factors, by R G Lewis and L Wallace
- Real-time on-line chromatographic determination of volatile organic emissions, by C W Bayer and M S Black
- Application of a multisorbent sampling technique for investigations of volatile organic compounds in buildings, by A T Hodgson and J R Girman
- A computer-controlled system for measuring ventilation rates of buildings using sulfur hexafluoride as a tracer gas, by L E Alevantis
- A tracer gas decay system for monitoring air infiltration and air movement in large single cell buildings, by J R Waters, G V Lawrance, and N Jones
- A multiple tracer system for real-time measurement of interzonal airflows in residences, by R C Fortmann, H E Rector and N L Nagda

Forthcoming Conferences

ENCIT '90
3rd Brazilian Thermal Science Meeting

10-12 December 1990
Hotel Plaza Itapema, Itapema, Brazil

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IAI Indoor Air International
International Conference: Priorities for Indoor Air Research and Action

May 29-31 1991
Hyatt Continental Hotel, Montreux, Switzerland

Further details from:

Priorities for Indoor Air Research and Action, PO Box 460, Biggleswade, Beds SG18 0AW, England, Tel: +44(0)767 318 474, Fax: +44(0)767 313 929

IBSPA-BS 91
Building Simulation '91
2nd World Congress on Technology improving the Energy Use, Comfort, and Economics of Buildings Worldwide

20-22 August 1991
Nice, Sophia-Antipolis, France

Further details from:

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ISEE 1991
1991 International Symposium on Energy and Environment

25-28 August 1991
Espoo, Finland

Further details from:

ISEE International Symposium, Energy and Environment, Helsinki University of Technology, Centre of Energy Technology, Otakaari 4, 02150 Espoo, Finland, Tel: +358 0 451 3580, Fax: +358 0 451 3419, Telex: 125161 htkk sf

Ventilation '91
3rd International symposium on ventilation for contaminant control

16-20 September 1991
Omni Netherland Plaza, Cincinnati, Ohio, USA

Further details from:

Ventilation '91, American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Building D-7, Cincinnati, Ohio 45211-4438, USA

Air Movement and Ventilation Control within Buildings
12th AIVC Conference

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Further details from:

AIVC, Barclays Venture Centre, University of Warwick Science Park, Sir William Lyons Road, Coventry, CV4 7EZ

PLEA 91
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ASHRAE, Program Coordinator, 1791 Tullie Circle, NE, Atlanta, Georgia 30329, USA

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Handbook (1983) Elmroth, A. Levin, P. 'Air infiltration control in housing. A guide to international practice.'

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4th 'Air infiltration reduction in existing buildings', Elm, Switzerland, 1982.
5th 'The implementation and effectiveness of air infiltration standards in buildings', Reno, USA, 1984.
6th 'Ventilation strategies and measurement techniques', Het Meerdal Centre, Netherlands, 1985.
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8th 'Ventilation technology - research and application', Uberlingen, West Germany, 1987.
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Representatives and Nominated Organisations

Belgium

*P. Wouters, Belgian Building Research Institute (WTCB/CSTC), Arlon Street 53, 1040 Brussels, Belgium. Tel: 02-653-8801 Fax: 02-653-0729

P. Nusgens, Université de Liège, Laboratoire de Physique du Bâtiment, Avenue des Tilleuls 15-D1, B-4000 Liège,Belgium. Tel: 041-52-01-80 Telex: 41746 Enviro B.

Canada

*M. Riley, Buildings Group, Energy Efficiency Division, Efficiency and Alternative Energy Branch, Energy, Mines and Resources Canada, Ottawa, Ontario, K1A 0E4 Canada Tel: 613-996-8151 Telex: 0533117 Fax: 613-996-9416

*J. Shaw, Inst. for Research in Construction, National Research Council, Ottawa, Ontario, Canada K1A 0R6 Tel: 613-993-1421 Telex: 0533145 Fax: 613 954 3733

J.H. White, Research Division, Canada Mortgage and Housing Corporation, Montreal Road, National Office, Ottawa, Ontario, Canada K1A 0P7 Tel: 613-748-2309 Telex: 052/3674 Fax: 613 748 6192

Denmark

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

P.F. Collet, Technological Institute, Byggeteknik, Post Box 141, Gregersensvej, DK 2639 Tastrup, Denmark. Tel: 42-996611 Telex: 33416 Fax: 45-42-995436

Finland

*R. Kohonen, Technical Research Centre of Finland, Laboratory of Heating and Ventilation, Lämpömiehenkuja 3, PO Box 206, SF-02151 Espoo 15, Finland. Tel: 358- 0-4561 Telex: 122972 Fax: 358-0-4552408

Federal Republic of Germany

*Prof. Dr.-Ing. F. Steimle, Fachinstitut Gebaude-Klima, Danziger Strasse 20, 7120 Bietigheim-Bissingen, Fed Rep Germany Tel: 071 42/54498 Fax: 071 42/61298 Telex: 7264754 fgk

J. Gehrmann, Projekttrager Biologie, Energie, Okologie in der KFA Julich GmbH, Postfach 1913, D-5170, Julich, Federal Republic of Germany, Tel: 02461/614852

Italy

*M. Masoero, Dipartimento di Energetica, Politecnico di Torino, C.so Duca delgi Abruzzi 24, 10129 Torino, Italy. Tel: (39-11) 556 7441 Telex: 220646 POLITO Fax: 39 11 556 7499

Netherlands

*W.F. de Gids, TNO Division of Technology for Society, Dept of Indoor Environment, P.O. Box 217, 2600 AE Delft, Netherlands, Tel: 31 15-696026 Telex: 38071 Fax: 015-616812

New Zealand

*M. Bassett, Building Research Association of New Zealand Inc (BRANZ), Private Bag, Porirua, New Zealand. Tel: 64-357600 Fax: 64 4 356070

Norway

*J.T. Brunsell, Norwegian Building Research Institute, Box 322, Blindern, N-0314 Oslo 3, Norway. Tel: 02-46-98-80 Fax: +47-2-699438

H.M. Mathisen, SINTEF,Division of App Thermodynamics, N-7034 Trondheim, Norway. Tel: 07-593870 Telex: 056-55620

Sweden

*J. Kronvall, Lund University, P.O. Box 118, S-22100 Lund, Sweden.Tel: 46 107000 Telex: 33533 Fax: 46 10 47 19

A. Logdberg, Swedish Council for Building Research, Sankt Goransgatan 66, S-112 33, Stockholm, Sweden Tel: 08-6177300 Fax: 08-537462

Switzerland

*P. Hartmann, EMPA, Section 175, Ueberlandstrasse, CH 8600 Dübendorf, Switzerland. Tel: 01-823-4175 Telex: 825345 Fax: 01-821-6244

UK

S. Irving (Operating Agent), Oscar Faber Consulting Engineers, Marlborough House, Upper Marlborough Road, St. Albans, Herts, AL1 3UT, Great Britain. Tel: +44(0)81-7845784 Telex: 889072 Fax: +44(0)81-7845700

*MDAES Perera, Environmental Systems Division, Building Research Establishment, Garston, Watford, WD2 7JR , UK Tel: +44(0)923 664486 Telex: 923220 Fax: +44(0)923 664010

M. Trim, Building Research Energy Conservation Support Unit (BRECSU), Building Research Establishment, Bucknalls Lane, Garston, Watford, Herts, WD2 7JR, Great Britain. Tel: +44(0)923 894040 Telex: 923220 Fax: (0)923-664010

P.J.J. Jackman, BSRIA, Old Bracknell Lane West, Bracknell, Berks, RG12 4AH, Great Britain. Tel: (0)344-426511 Telex: 848288

USA

*M. Sherman, Indoor Air Quality Division, Building 90, Room 3074, Lawrence Berkeley Laboratory, Berkeley, California 94720, USA. Tel: 415/486-4022 Telex: 910-366-2037 Fax: 415 486 5172 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: 301/975-6413 Fax: 301/975-4032

J. Talbot, Department of Energy, Buildings Division, Mail Stop Ce-131, 1000 Independence Avenue S.W., Washington D.C. 20585, USA. Tel: 202/586 9445 Telex: 710 822 0176 Fax: 202 586 4529/8134

*Steering Group Member

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Air Infiltration and Ventilation Centre
University of Warwick Science Park
Barclays Venture Centre
Sir William Lyons Road
Coventry CV4 7EZ, UK

Telephone: (0203) 692050
Fax: (0203) 416306

Head of Centre Martin W Liddament

Operating agent for IEA Oscar Faber Consulting Engineers, UK