PROGRESS AND TRENDS IN AIR INFILTRATION
AND VENTILATION RESEARCH

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Poster 23

INFILTRATION AND VENTILATION IN SWITZERLAND - PAST AND FUTURE

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1. CLIMATIC CONDITIONS, BUILDING CONSTRUCTION AND USER NEEDS, AN INTRODUCTION TO VENTILATION IN SWITZERLAND

The Swiss, it is said abroad, all yodel and are closely aligned with agriculture (Swiss cheese). This stereotype represents only a small part of the population, whereas ventilation by means of windows (in residential buildings) is in fact a national characteristic. Critics call the Swiss ventilating customs "random ventilation" ("Zufallslüftung") and this expression is in fact on target. It is regretable that the populace still have no means on hand to overcome this randomness. In any case, there are a few points which will be reported here. Also regretable is the fact that in the last 20 years, window constructions with finely adjustable sash - such as the sliding unit pictured here (part of a casement window with two panes in series) - have been replaced with large side or bottom hinged sash. The following observations are, as a rule, applicable for residential construction.

Why has the Swiss random ventilation system not been replaced? The answer lies in the fact that, for a large part of the Swiss people and for the greater part of the year, the amount of air changes in a room is not as important as it is in other places. This can be explained by several facts:

- Very cold days occur very seldom so that the heating systems, which are often dimensioned with a generous safety factor, can meet the heating demand even if one or the other window is left open too long.
- Very hot days, when window opening at night would improve comfort, occur seldom.
- The buildings were better insulated than was the case in neighboring countries, with the result being that mildew problem occurs less often.

Naturally, there are extreme climate situations, also alpine regions, which are much colder and more wind exposed than the average. There, as a rule, the building occupants understand the appropriate behavior regarding controlling ventilation (e.g. a protection zone before the house entrance door, the closing of shutters and the weatherstripping of casement windows).The Swiss climate data and construction guidelines were written up and illustrated in detail in the first AIVC

Handbook (the Swedish Handbook). In this regard a few summary statements are appropriate.

For the majority of buildings:
- massive construction is the rule,
- in alpine regions post and beam construction also occurs,
- prefabrication is rare,
- double glass windows have been common for a long time.

Regarding residential ventilation:
- older houses had natural ventilation shafts,
- bathrooms and toilets as well as kitchens had windows.

2. DEVELOPMENTS IN THE DESIGN OF BUILDING COMPONENTS AND VENTILATION SYSTEMS DURING THE LAST DECADE

The extensive efforts to save energy and the multitude of ensuing energy saving guidelines have lead to the drastic reduction of heat losses due to transmission through the building envelope. Thereby, there has been a drastic increase in the proportion of the heat losses caused by infiltration. For all building surfaces the U-value has been reduced, while the construction in general and windows in specific have become increasingly airtight. This has led to the fact that, for massively constructed buildings, the air change rate is too low. In light construction the previously extreme leakiness has now been reduced to an acceptable level. (Also, noteworthy is the growing trend to convert attic space into a habitable room.) By contrast, methods of providing ventilation have not benefited from any appreciable improvements. It is true that mechanical ventilation has become increasingly common for interior bath rooms, toilets and for kitchens. There is in general, however, no overall ventilation concept for houses (for example, the conscious placement of ventilation openings, including adjustable sash or dampers or an indicator which advises: "Please open the windows now because it has become too humid").

In parallel to these construction developments of the post energy crisis era, a small group of designers and building physicists have pursued interests regarding questions of air quality, the end effects of inappropriate ventilation and the consequences of a leaky building envelope. Their investigations have been supported through the AIVC and through intensive association with researchers abroad. As a result of these efforts the following has been possible:

- The actual air exchange situation in our buildings has been determined.
- Dependable measurement methods and equipment have been developed and tested (airtightness, air change rates, and locating leaks).
- Efforts have been initiated to develop Swiss design guidelines regarding airtightness and ventilation.
- Interest has grown in developing planning tools and systems adapted to the conditions of the future.

We shall report on recent developments in Section 3 and particularly in the report on research results in Section 4.

3. OUTLOOK, SUPPORT OF RESEARCH ACTIVITIES

The authors are of the opinion that for a large number of Swiss buildings a major change in the means of ventilation will follow. This change will be of the same magnitude as the drastic increase in the insulation of the building envelope or as the halving of window transmission losses. What are the underlying causes for such a major change. A few key aspects can be noted:

- The air exchange rate in most existing buildings is known to be too small (basic air change rate) with the result being too high concentrations of CO_2 in unventilated bedrooms.
- The ever increasing noise burden has led to rulings to subsidize the installation of acoustic windows; other measures have not followed in parallel.
- In new buildings materials are used which emit odors/pollutants. In combination with tight windows and random ventilation the threat of health hazards of many sorts is very real.
- From experiments in other countries and from a few case studies in Switzerland new types of solutions to these problems are known. These have an economically viable outlook, and promise reduced energy consumption and good indoor air quality.

- Finally, building occupants have become more critical. The "sick building syndrome" and "Wohngifte" have prompted industry to find innovative solutions to these problems.

What distinguishes these new solutions? At least three major steps towards the future can be identified:

- Two years ago an extensive basic research program (ERL) was started (see paragraph 4).
- An intensive effort in writing design and measurement standards has been instigated (Standards concerning ventilating equipment; building regulations judging the necessity of ventilation, cooling and humidification equipment; and guidelines for on site measurement).
- Finally multiple steps have been taken concerning systems development, including work done in the context of:
  - the ERL-Programm, particularly commercial buildings,
  - the IEA Annex 18 concerning demand ventilation in general (active Swiss participation),
  - a series of Swiss projects ("Impuls Programs") in regard to ventilation in apartments; mechanical ventilation with and without occupant involvement should be tested (particularly humidity regulation systems),
  - a planned research project involving ventilation of large volume rooms (e.g. atria and halls).

If and when these developments will occur on a large scale is a matter of speculation. In a broader context, a push for better controlled ventilation will occur with the opening of the European Market in 1992. At that time manufacturers with large series production will create a pressure on the Swiss market. Hopefully, the products which then appear will not embody mediocrity as a result of market pressures, but rather will fulfill their function with superiority.

4. ENERGY RELEVANT AIR MOVEMENT IN BUILDINGS

Interim Report, Status June 1989

4.1 Introduction, Goals

Starting point, organisation

In 1985 the research program "Energy Relevant Air Movement in Buildings" (ERL) grew out of the concept for an energy policy developed by the Swiss Directorate of Education. In 1986 this concept became a reality, addressing two fundamental issues: the transport of air and contaminants within a building and the exchange of air between a building and the outdoor environment. To deal with these issues three subtasks were defined:

- Subtask A: Air and contaminant flow within a room (intrazonal air movement)
- Subtask B: Air and contaminant flow between rooms and to the outdoor environment (interzonal air movement)
- Subtask C: Ventilation systems of the future.

The interdisciplinary nature of the program requires the cooperative efforts of several institutes of both Swiss Federal Institutes of Technology in Zürich (ETHZ) and Lausanne (EPFL), the Swiss Federal Laboratory for Materials Testing and Research (EMPA), several industry firms and various engineering firms. The scientific work, organized into Subtask topical areas, was divided into individual projects. Financing of these projects has been provided from five sponsors: The Swiss Federal Office of Energy (BEW), the National Energy Research Foundation (NEFF), the Commission for the Advancement of Scientific Research (KWF), the National Fund (NF), and the Directorate of Education.

In the following two chapters the problem area of this work is presented along with the goals which were defined at the inception of this program. Thereafter, the present status of the work is reported.

The Problem Area

The air flow within a room, the interchange of air between rooms and the interchange of air between a building and the exterior are topics which until today have received little attention by researchers. The processes are three dimensional, time dependent and take place under complex conditions (weather, occupant behavior and spatial definition). The design of an HVAC system today must draw principally on experience, taking into account all of the above mentioned uncertainties and including conservative safeguards. Today a key concern is to achieve low energy consumption while affording comfort of the occupants. However, more knowledge is needed regarding the mechanisms of airflow, the associated heat and material transport (contaminants) and the criteria for judging the feeling of well-being in a room. The currently available numerical simulation and measurement techniques promise exciting opportunities to deepen our knowledge in these areas of air movement. This improved understanding can then be applied in the planning of buildings and HVAC systems with the end result being the development of more economical systems, better indoor air quality and increased confidence in the performance of buildings and systems optimized for low energy consumption.

Goals

The designers of buildings and HVAC systems should be provided the means of evaluating all the relevant parameters regarding air movement in buildings in order to assure:

- The occupants' well-being, comfort and safety.
- A suitable and economic system for ventilation and heating.
- An extensive use of insolation and internally generated heat.
- An optimal use of purchased energy.

The Swiss conditions of climate, weather and building construction will be given special attention throughout the program. The following steps are envisioned:

- Development of a mathematical description of the air and contaminant transport within a room and between different zones of a building.
- Provision of a method of measuring velocity of air movement and its variation, air temperature and the concentration of contaminants.

- Clarification of which ventilation and heating systems are best suited for different building types (occupancies).
- Translation of the results into design tools, which when possible do not require a mainframe computer.

This overall area of concern can best be addressed by dividing the subject area into three subtask areas:

- Subtask A: Air and contaminant flow within a room.
- Subtask B: Air and contaminant flow between rooms and to the outdoor environment.
- Subtask C: Ventilation systems of the future (for various building types/occupancies).

The goals of these and the interim status of the work are reported in the following section.

4.2 SUBTASK A: Air Movement and Contaminant Flow Within a Room

The work of this Subtask should provide the means of calculating those air movement parameters which are key to assessing the energy and comfort performance of a ventilation and heating system. Also, measurement methods for determining the air flow processes, either in a physical model or on site in a building, should be refined. The results will also be so formatted as to serve as input data for defining the single room conditions to be used in Subtask B. Further they will serve as a basis for the investigation of concepts for future HVAC systems conducted in Subtask C.

In the now completed first step of the project, the suitability of the finite difference method (FD) of calculating air movement in rooms was investigated at the ETHZ. To validate the algorithms of the program package PHOENICS measurement data from well defined test cases were used. These test cases were conducted in the test chamber of the Company Sulzer Brothers using a laser-doppler measurement system (LDA). It was thereby shown that both two and three dimensional problems can be easily defined and solved using PHOENICS. For laminar air flow, as a first estimate, good results were also obtained. This was also true for isothermal, momentum driven, turbulent air flow. If the thermal buoyancy becomes prominent, it would be necessary to extend the turbulence algorithm (k-ε-model) in PHOENICS. For this purpose validation efforts are now in progress.

In addition the firm Sulzer used AIRCOND (an FD program) to calculate heat transfer for given temperature conditions. For the anisothermal case of free and mixed convection, improvements in the model had to be made. Also, for the determination of heat transfer coefficients by free buoyancy modifications had to be made to the model. Further modifications improved the convergence and the calculation run time of the program. The greatest promise for further development lies, however, in hardware advances (parallel processing).

In general it was determined through comparisons of computed and measured data that good agreement occurs in the case of isothermal momentum driven air flow and acceptable agreement occurs for anisothermal buoyancy driven air flow. Model improvements are, none the less, necessary. This work comprises a part of our contribution to Subtask 1 of the International Energy Agency (IEA) Project "Air Flow Patterns within Buildings". Through this cooperative effort essential support and contributions were also received.

A major goal of the work in this Subtask is the delivery of simplified calculation procedures for designers. These tools deliver results of acceptable accuracy at substantially less cost. For this purpose first ideas have been developed.

In parallel to the above mentioned work with FD methods, a team at the ETH-Lausanne will develop a program using the finite element (FE) approach. The method will be checked against the same test cases which should promise to be an interesting comparison concerning possibile applications of these two approaches. The special advantages of the FE method are expected by non cartesian geometries as well as by the calculation of air flow details (e.g. air entry zones, air flow around people and equipment, etc.). This work is now in a beginning phase.

The glass fiber LDA apparatus, adapted by the firm SULZER for this project, has proven to be very useful. By means of this non-disturbing optical method instationary air flow with very small air movement velocities and a high degree of turbulence can be investigated. The method allows measurement of a spatial air flow field on a point basis by determining the components of the velocity vectors from two directions. Thereby, the method proves to be very appropriate for the validation of computer programs which calculate air movements. As a portable device for conducting field measurements the method is less well suited because of its complex construction. The volumetric results discussed until now fulfill the laws which were expected. For determining the instability of air flow with very low frequencies (approximately 0.1 Hertz), the system should be expanded to allow the simultaneous measurement of all three velocity components.

As a compliment to this technique a tracer imaging technique will be developed to help visualize and quantify a complete air flow field. This work is to be done outside the scope of the ERL Project at the ETH in Zürich. The method is based on computer supported image processing of tracer tracks (soap bubbles) in a darkened room. The tracer movement is made visible by means of a special optical approach (light sheet method). This approach could, in its principal mode of operation, be readily validated. The construction and testing of a portable apparatus is currently in progress.

4.3 Subtask B: Air and Contaminant Flow Between Rooms and to the Outdoor Environment

The original goal of the Subtask B is still valid, namely, to develop a simplified calculation program to predict the air and contaminant flow between rooms and between a room and the outdoors. For the occasion of the last "Swiss Status Seminar" in 1988, the latest possibilities for using such a program for evaluating variations of a buildung and its equipment were definded. Also, the grouping of the work remains as originally planned, namely:

- Program development
- Definition of a suitable measurement technique and collection of data for program validation.
- Working out detailed physical phenomena (interaction of wind, thermics; characterization of the occupant behavior; preparation of climate input data recognizing the specifics of the topography and built-up environment).

Changes have occured, however, in the leadership of the Subtask. J. Hertig replaced the Subtask initiant and original leader, Ch. Zürcher. This was neccessary because support of the activity was lacking on the part of the ETHZ. This left a critical gap in the topical groups: detailed physical phenomena and program development. It remains to be seen to what extent the consequences will be merely a delay in the time schedule or an adjustment of the responsiblities of the group. The situation is somewhat less critical due to the international cooperation in these activities (COMIS and the IEA Annex 20). The status of the Subtask as of the end of 1988 can be described as follows:

- The specifications for the computer program have been coordinated with the COMIS project.
- A phase of joint work between the Swiss principal researchers and the COMIS team has been fixed.
- The partially completed work on statistical description of the behavior of occupants was begun and led to an overview of available measurement data and to a first model.

Only minimal delays have been suffered in the evaluation and correction of ANETZ wind data. The publication of a report and calculation rules is expected by the end of 1989. In addition, supporting tests in a wind tunnel were carried out upon completion of the necessary topographical dummy forms. As planned, the preliminary study for the planned research on thermal kinetics and air exchange in buildings was completed. A detailed plan for the whole project is now available. Also completed is the development of a tracer gas method CCGT (constant concentration with the use of three gases) for the investigation of air exchange and contaminant transport. Meanwhile, the work on the EDA-Method (PFT-Tracer-Method; constant emission, absorbers) is still underway. An apparatus for determining the air permeability or airtightness of buildings or zones within buildings is now operational at the EPFL/LESO.

The team of the EPFL/LESO has determined with great care all the key parameters of the LESO building and for selected periods quantified the air change rates. These reference data sets should prove useful for the COMIS calculation program as well as for the future variations of the ERL multizone computer program. A sensitive hole in the construction of the ERL multizone program is the not yet completed structuring of the Swiss building population and accordingly the appropriate modification of the wind fields in the close proximity to the building. For 1989 several preliminary studies are planned, but it will be difficult to allocate the priorities among the experienced researchers.

4.4 SUBTASK C: Ventilation systems of the future.

The goal of the work of this Subtask is the advancement of the development of future-oriented heating, ventilation and cooling systems for buildings with air as the transport medium. The project encompasses building types of various categories: residences, schools, office buildings and industrial buildings. The focus of the investigations lies by commercial buildings (defined to include office buildings, schools, banks, etc).

In the first phase of the project, a comprehensive data survey, literature review and questioning of "opinion leaders" (researchers, manufactures, system designers, contractors and installers) and real estate owners has been assembled and will now be evaluated. Thereby, a realistic picture of the status of the technique and the capabilities of the different systems should be possible. In addition, new insights about the necessary improvements of the planning and dimensioning material should be gained. Lately, it has become common to expect a high degree of thermal insulation of the building envelope, increased air tightness of construction (energy conservation measures) and escalating room air quality and comfort. One particular need of designers concerns the optimization of the ventilation system for different building types. Designers need answers regarding necessary fresh air quantities, air quality and energy balances. Consideration must also be given to improved controls responding quickly to changing loads. Finally better understanding is needed of room air movement, internal heat sources and occupant behavior.

On the experimental side, a preliminary (qualitative) investigation of new systems has been started as case studies. Here, smoke tests in rooms will be used to determine the air movement behavior in rooms. The quantities of air supplied and exhausted, humidity, CO_2 concentration and relevant temperatures will also be determined.

An additional area of investigation concerns the free and forced convection in an apartment building. Concerning this latter subject, interesting results have already been obtained on comparisons of the air change rate by natural and by mechanical ventilation, and on the influence of occupant behavior on the thermal energy balance. In the ongoing measurement phase, moisture measurements and CO_2 measurements are being conducted. From these results it should be possible to obtain a rough picture of the energy and contaminant transport in rooms with natural ventilation.

A final report on the results of the first phase of the project should become available shortly. Besides a description of the present state of knowledge on ventilation systems, the report contains material on new development tendencies in Switzerland and abroad, the needs of building clients and designers and experiences with newer systems (case studies). Through the joint work started in 1988 with the IEA Annex 18 "Demand Controlled Ventilating Systems" the necessary international connections have been provided. This cooperative effort brought, in addition to an overview and analysis of sensor technics, experience in the measurement of characteristic parameters for determing the ventilation efficiency of systems.

With the implementation of an advisory panel from industry, a vital link to practice has been achieved. This is of great importance for the practical application of research results. The concept for disseminating results for Subtask C is determined together with the participants of IEA Annex 18 and the potential users in Switzerland.

In the second phase of the project a test chamber will be used to clarify uncertainties of systems and to test new systems. Of primary interest in these investigations will be pure air systems (all-air) and systems with separated ventilation and heating/cooling components. To be determined is the influence of the major parameters of the systems (the system use conditions as well as the building use) upon the deployment, economics and energy savings potential of the systems. The behavior of the systems by practical uses should be examined. These investigations will concentrate on commercial buildings in the larger context of this definition. Ventilation of apartment buildings and special ventilation systems in the industrial sector shall not be considered.

4.5 Outlook

After completion of the first phase, necessary modifications to the original enthusiastically set goals have become evident. In Subtask A the interim goals were most closely achieved regarding the development of numerical methods. Here, the work is also the most advanced. However, the development of measurement methods and the preparation of relevant data for design materials must be reduced. For example, the LDA method for the point measurement of air flow proved to be an outstanding for the validation of computer codes, as a portable apparatus for application in field measurements it proved, however, inappropriate. Limitations were reached in the calculation of air flows in complex large spaces, in the determination of emission and absorption data of building materials (transport of contaminants) as well as of the propagation of specific heavy air contaminants.

In Subtask B problems appeared by the accurate determination of pressure distribution in border zones of single rooms/ subparts of rooms. Also problematic is the determination of the reference data (temperature and pressure), as they are influenced by many factors such as the surroundings of a house.

In Subtask C gaps exist in the planned field measurements as a consequence of lacking measurement techniques. It will have to be determined in detail to what extent these will affect the output of the project. As regards to investigation by building types, it is clear that in Switzerland the main interest lies by commercial buildings (office buildings schools, banks, hotels, etc.). In the industrial sector the requirements of a ventilation system are so different and specific (often for extreme circumstances) that practically a special solution must be found for every single situation. Therefore, the ERL-C Program will concentrate on commercial buildings. The focus of the third phase of the subtask will be the dissemination of the results for use in the practice. Scientific reports and data bases for future research projects and international collaboration will be prepared by the researchers. But, of specific importance are the directly useable products of the work, namely, well documented calculation and measurement methods, and a sourcebook. These materials should then be integrated into a handbook for designers. Because this document is aimed to serve designers, designers must have an influence during its creation. In all of the above the interests of several target groups must be taken into account. These groups have been defined as:

- Researchers (national and abroad)
- System designers (in the larger context)
- Architects and their clients
- Schools (University and technical schools)
- Software firms (producers and marketers).

How the newly gained results and directly useable products are transferred will be determined in discussions with the different target users.

4.6 Examples of results from each subtask

Subtask A:
"Test case with natural convection"

3-D Laser-Doppler Anemometry (LDA) measurements have been conducted in a test chamber (below) to evaluate the performance of the flow simulation code AIRCOND in predicting natural convection.

Non-isothermal Flow with Free Convection

Measured quantities:
U, V, W, u-rms, v-rms, w-rms, uv, uw

Seeding:
Paraffin oil droplets = 0,5-2μm

Data rate:
5-50 [1/s]

Averaging over:
ca. 3000 Samples

Accuracy:
Velocity: ±1% - ±10%
flow angle: ±3%
Position in the room: ±10mm

Measuring time:
2D: 10 min
3D: 25 min

Number of measurement points: 330

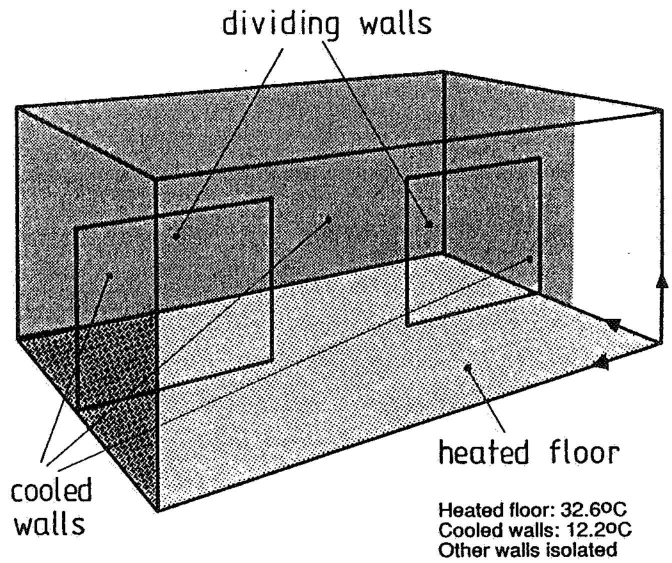


Figure 1: Test case and its characteristics

Non-isothermal Flow with Free Convection

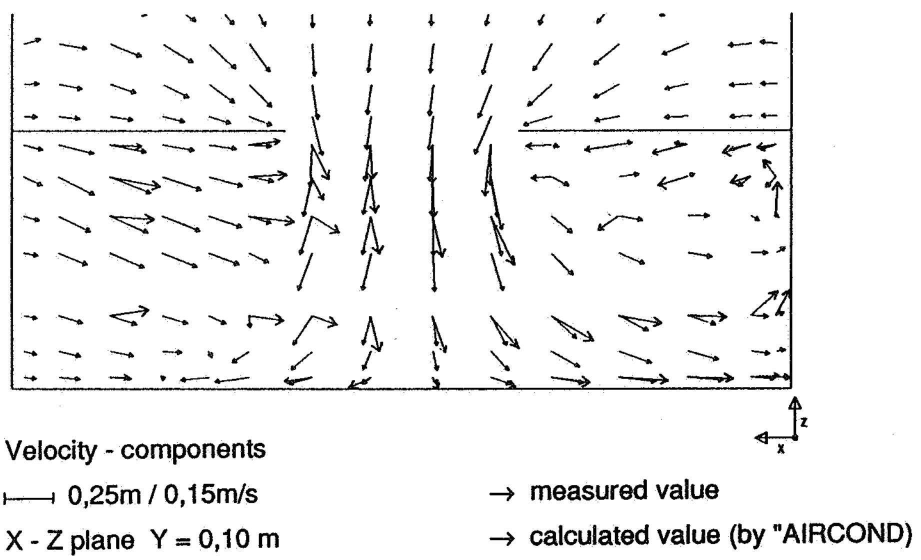


Figure 2: Comparison of measured and calculated airflow

Comparison of the velocity field in a horizontal plane 10 cm from the floor of the room: computation (black arrow heads) agrees well with measurements (open arrow heads) for the cold flow between the dividing walls but is in error in the recirculating zone at right. AIRCOND* uses the standard k/ε-Model and empirical correlations for natural convection heat transfer.

* (AIRCOND is distributed by AVL, Graz)

<u>Subtask B:</u>
<u>"Stochastic analysis of users behaviour in regard to ventilation"</u>

Goal:
To develop stochastic models of user behaviour regarding ventilation using the theory of probability. These models will be able to generate synthetic time series of window and door openings whose characteristics will be similar to reality. They will be integrated in to air ventilation simulation programmes to improve their accuracy and realism.

Method of work:
- Collect the appropriate monitored data regarding window and door openings (LESO test building)

- Determine the most appropriate influential variables
- Develop stochastic models using simple stochastic processes (Markov chains)
- Apply the models to different rooms and users behaviour (direct gain facade, high insulation technique)
- Validate the models via comparison with reality
- Publish a short description of the models and their application procedure.

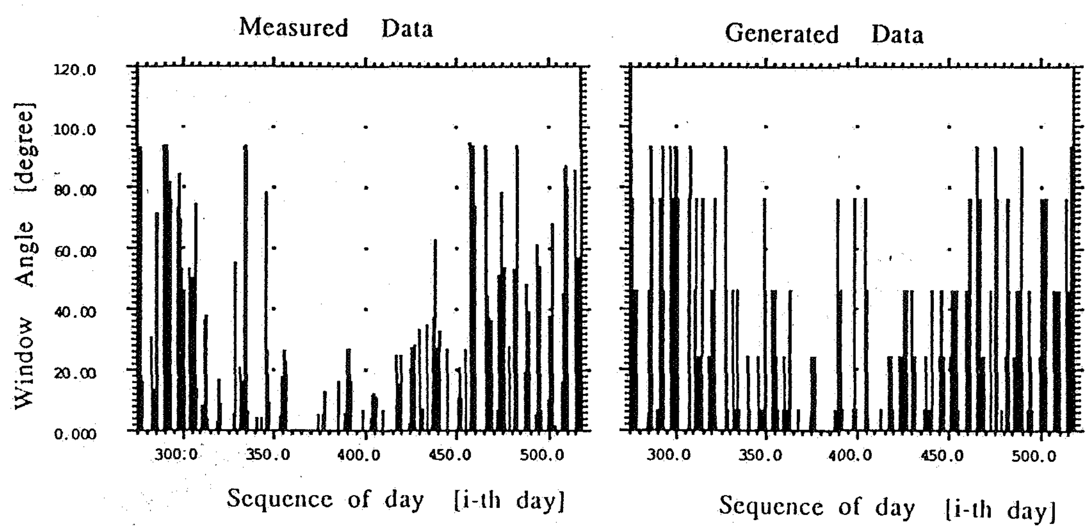


Figure 3: Measured and generated data

Real and synthetic time series of window angles (LESO test building, winter 1984-85, direct gain room west). Synthetic data are discretized for purposes of stochastic modelling, showing a less "continuous profile" then real data. Impact of this on simulation results is not significative.

<u>Subtask C:</u>
<u>Investigations on 10 built examples</u>

Goals of the case Studies

- Overview over modern ventilation systems for office buildings and dwellings in Switzerland
- describe the behaviour of systems under real working conditions
- determine air quality and thermal conditions in the room
- visualize air flows in the room

Investigated system types

1. Complete mixing
   - induction
   - fan-coils
   - ceiling outlets (jets)

2. Displacement ventilation
   - low-level diffusers
   - ceiling diffusers
   - floor mounted twist outlets

Investigation Programme

1. Global building description

2. Building construction

3. Main ventilation system
   - air conditioning
   - air distribution

4. Local ventilation system
   - principle of ventilation
   - supply and exhaust devices
   - room conditions (air quality, thermal comfort)

5. Control and flexibility

6. Influence on the joice of the system
   - contractor
   - architect
   - engineer

7. Measurements
   - air movements
   - temperatures
   - CO_2
   - humidity

8. Smoke trials
   - visualization of the air flow patterns

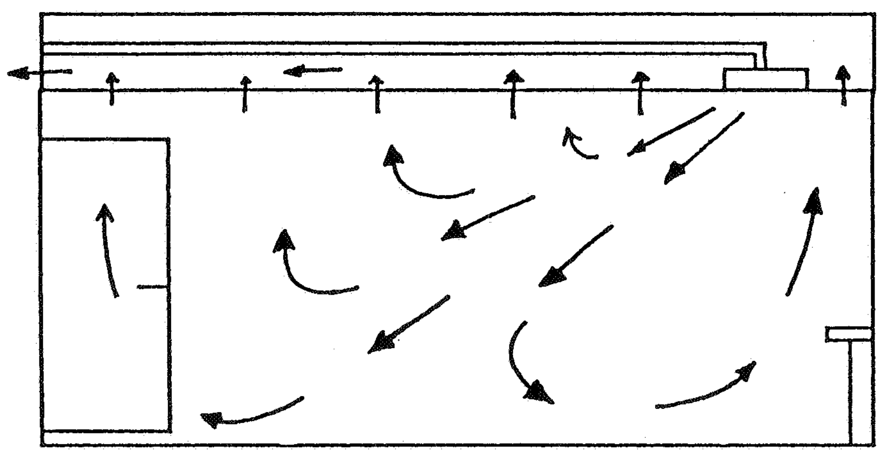
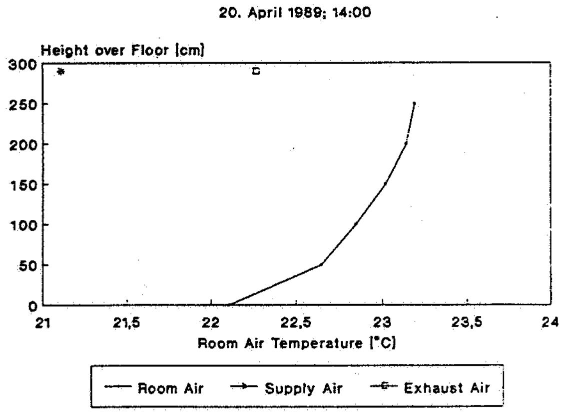


Fig. 4: Typical air flow pattern determinded by smoke visualization System type: Complete mixing / ceiling outlet



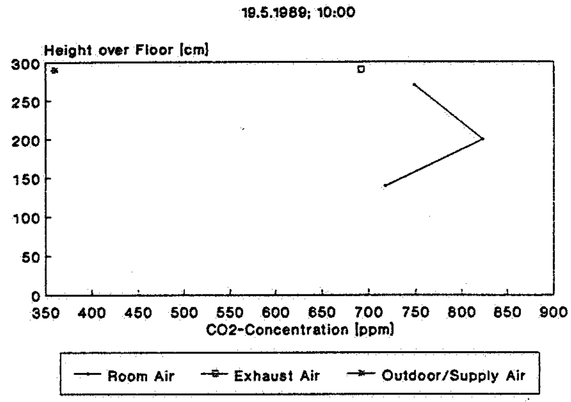


Fig.5: Typical measurement results
System type complete mixing / ceiling outlet

4.7 Relationship of the ERL Research Programme with the Plans of Other Countries.

In the last year and also today there has been a major effort on the part of the Swiss to start and participate in appropriate international projects. One example is the initiative for a first exchange of experience concerning air exchange which took place in a seminar in 1968. Another example is a first effort for a "window ventilation project" which was followed by a real project start 5 years later.

At the present time four projects, in which the ERL team is involved, are in the foreground:

- The Air Infiltration and Ventilation Centre (IEA "Buildings" Annex 5).
- The "IEA Buildings Annex 18", "Demand Controlled Ventilation Systems".
- The "IEA Buildings Annex 20", "Air Flow Patterns within Buildings".
- The LBL instigated project "COMIS".

It is evident that all ERL researchers can profit from the basic work and publications of the AIVC; that Annex 18 is complementary to ERL Subtask C, that ERL Subtask A profits from support by Annex 20. Finally the work in Subtask 2 of Annex 20 as well as the work of COMIS are well linked to the work of the ERL Subtask B. It commands from the researchers, however, an intensive concentration and common thought process at international project meetings. In this context it is possible to list products desired from this planned work, which are not unrealistic:

- From the AIVC: a clean list of definitions about ventilation efficiency. An updated version of the measurement technique guide and the editing of a new version of the calculation guide.

- From Annex 18: narrowly grouped, strictly conceived field tests about demand controlled systems.

- From the participants of the COMIS Program: a good description (source book) of their results.

4.8 Publications

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[2] Wiss D., Metzen G., Borth J.:"Numerische Simulation von Strömungen und ihre Verifikation", Technische Rundschau Sulzer, 3/1986

[3] Feustel H.E., Scartezzini J.L.: "Development and validation of a simplified multizone infiltration model", Proc. of ICBEM'87 (1987), #2721

[4] Roulet C.A., Scartezzini J.L.: "Measurement of air change rate in an inhabited building with a constant tracer gas concentration technique", ASHRAE Transactions 93/1 (1987), #2882

[5] Scartezzini J.L., Fürbringer J.M., Roulet C.A., Feustel H.E.: "Data needs for the purpose of air infiltration computer codes validation", Proc. of 8th AIVC Conf., Ueberlingen, FRG, Sept. 1987

[6] Zollinger H.J., ed.: Forschungsprogramm "Energierelevante Luftströmungen in Gebäuden", Tagungsunterlagen 1.Statusseminar, Winterthur, Nov. 87

[7] Scartezzini J.L.: "Programmes de calcul détaillés et simplifiés des échanges d'air dans le bâtiment: validation à l'aide de mesures expérimentales", Statusseminar ERL, Winterthur, Nov. 1987

[8] Roulet C.A.: "Energierelevante Luftströmungen in Gebäuden", 3. Weimarer Symposium, Weimar, DDR, 1988

[9] Zollinger H.J.: "Energierelevante Luftsströmungen in Gebäuden", Technische Rundschau Sulzer, 2/1988

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<u>Remark:</u> The annual progress reports of the particular subprojects are published in [6] and [17] and not quoted here. Copies of [6] and [17] are still available and can be ordered by Dr. F. Widder, Paul Scherrer Institut, CH-5232 Villigen PSI (Switzerland)