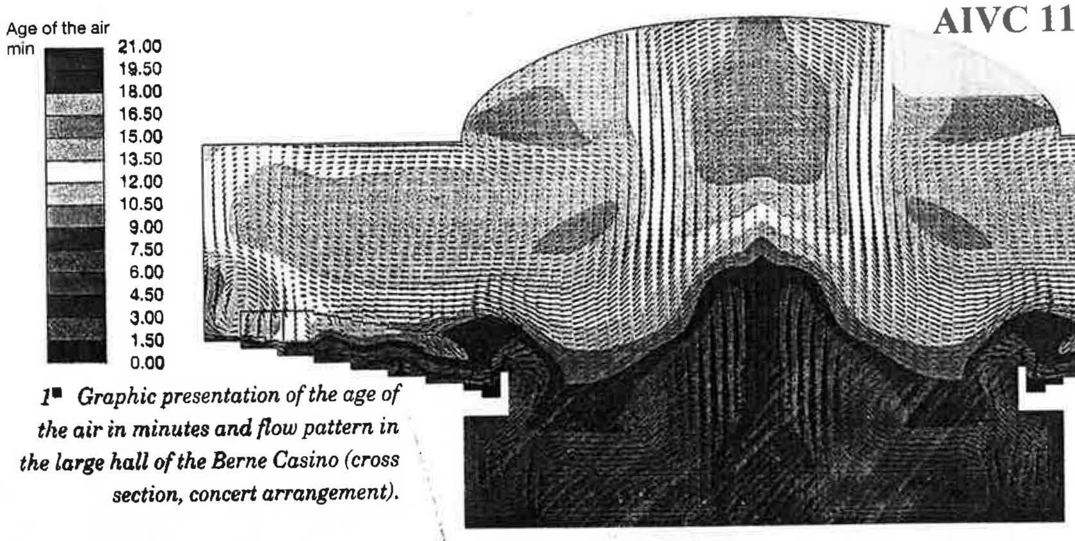


1■ Graphic presentation of the age of the air in minutes and flow pattern in the large hall of the Berne Casino (cross section, concert arrangement).

Simulation for Safety Planning

PETER KOFOED
SULZER INFRA
JOACHIM BORTH
SULZER INNOTEC

Though experience is still very important in ventilation and air conditioning, conventional approaches are often no longer adequate where large rooms and new technologies are involved and big energy savings are demanded. By resorting to numerical simulation it is possible to represent virtually air flows, temperatures, propagation of noxious substances and other variables by computer, thereby arriving at economical and ecological alternative solutions.

One way of dealing with even complex ventilation problems is by flow simulation on the computer. Once the building shell is digitized and the machinery, installations, people or outside climatic conditions are converted into bits and bytes, the room climate can be calculated by high-power computers and then viewed in a virtual room on the screen, or put onto paper by graphics with high information value (Fig. 1■). Temperatures and air flows in the room are made visible, undesirable eddies or deadwater zones are revealed, and particle concentrations can be determined. Variations of the boundary conditions for investigating summer or winter situations or verifying the effect of a different air ducting, can be performed speedily. In other words, the room climate can be varied artificially.

SIMULATION DEFEATS COMPLEX PROBLEMS

The prime purpose of simulation is the representation of flow patterns by means of computers. The transient continuity equations for mass, impulse and energy have long been known from physics, but the solution of these differential equations became possible only by turning to numerical mathematics and high-power computers. The analyzed zone, for example an office room, is presented digitally by means of a CAD system. This room is then broken down into a very large number of volume elements. At the boundaries of the calculated zone, boundary conditions are stated, such as wall temperatures or incoming and outgoing air flows. Numerical solution of the flow equations then provides for each volume element the three components of the air velocity, the temperature and the values of other calculated variables. As the number of volume elements increases, so does the accuracy of the result and the computing outlay.

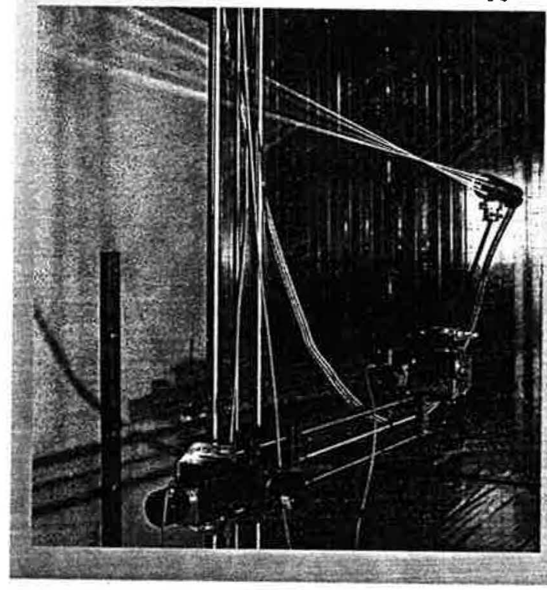
Together with Sulzer Innotec AG, Sulzer Infra Lab AG (a subsidiary of Sulzer Infra) has developed to perfection the simulation of room climate (i.e. the calculation of three-dimensional room air flows) and is able to provide the designer with an effective instrument for making further decisions. A special computer program and a powerful computer are used in the process.

THE AGE OF THE AIR

The age of the air is the period of time it takes for a molecule of air to enter and pass through the supply air outlet and to reach a certain point in the room. The younger it is, the better the quality of the room air.

UP-TO-DATE METROLOGY

The glass-fibre laser Doppler anemometer (LDA) is an instrument for measuring air velocity and direction. This method measures the velocity via the frequency shift of laser light scattered by moving particles in the air (Doppler effect). Aerosols are put into the air to provide the particles. The laser light is transmitted from the measuring probe to the data acquisition system by a glass fibre cable.



Laser Doppler anemometer probe with traversing mechanism.

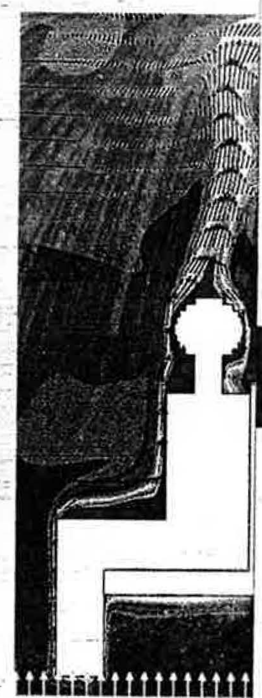
TESTS ARE STILL IMPORTANT

The actual know-how lies not only in the computer calculation but also in the formulation and the physically correct simplification of the boundary conditions for temperature, volume and energy flows, and for sources of smells and noxious substances. Together with the external conditions – data on the building shell, machinery, installations, workplaces and similar (Fig. 2■) – the prerequisites are assured for working with the three-stage program (preprocessing, flow calculation and postprocessing).

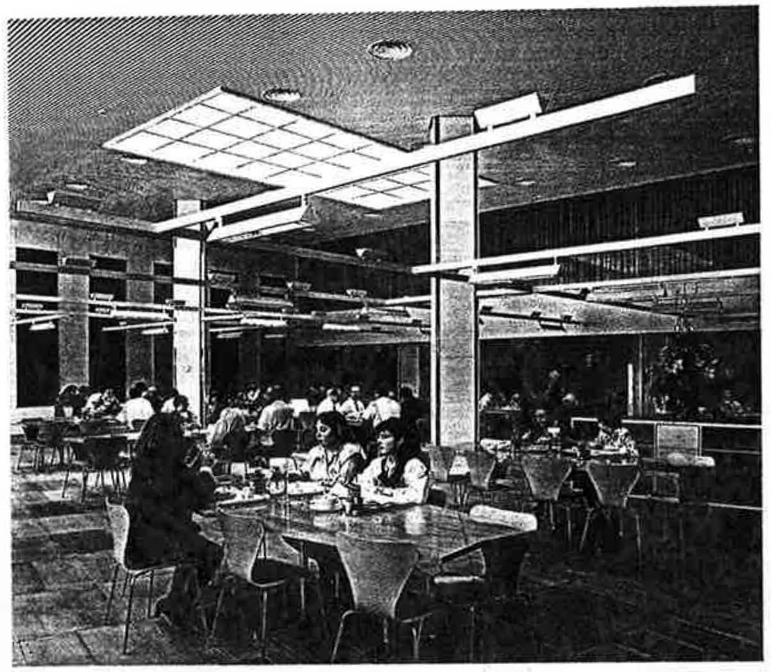
Is simulation a universal instrument then? Certainly not, for the calculation methods had to be adapted to the special conditions of room air flow patterns. Numerous tests are carried out in our own air flow laboratory, in order to check periodically the results of numerical simulation. For example with the help of a glass-fibre laser Doppler anemometer (LDA) the velocity components of a three-dimensional flow were measured in a room provided with inlet and outlet ducts and models of various equipment (cf. box). Equally important are field tests on existing objects. Once measured in a test, the digitized measured data are then available for repeated use. By means of them, computer simulation can be developed further or boundary conditions provided for simulation. Consequently numerical simulation should not be overrated: as a method it is a major supplement to laboratory or field tests but it can never replace them entirely.

ONLY CUSTOMER BENEFIT MATTERS

Numerical flow simulations are not an end in themselves but an efficient design tool. The simulation results enable the heating, ventilation and air conditioning designer to advance to the limits of technical feasibility. Only by this can plant and operating costs be minimized further.



2■ Flow values around a seated person with theatre seating and air outlets in the floor



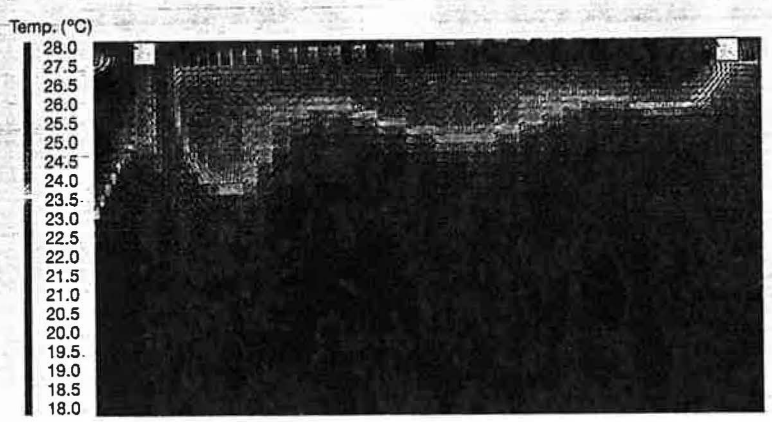
3■ *Staff restaurant with circular air outlets in the ceiling.*

The advantages are:
- simpler handling of complex ventilation problems;
- cost-cutting by omitting model tests;
- security and minimization of technical risks already at the initial design stage;
- innovation by testing alternative solutions already at the design stage;
- low-cost and speedy visualization of flow patterns (costs: a few 1000 Swiss francs; time taken: less than two weeks);
- visualization of system behaviour made visible by colour graphics and video presentation (air temperature and velocity, flow direction, turbulence degree, air quality and particle propagation);
- manufacturer-neutral analyses and recommendations.

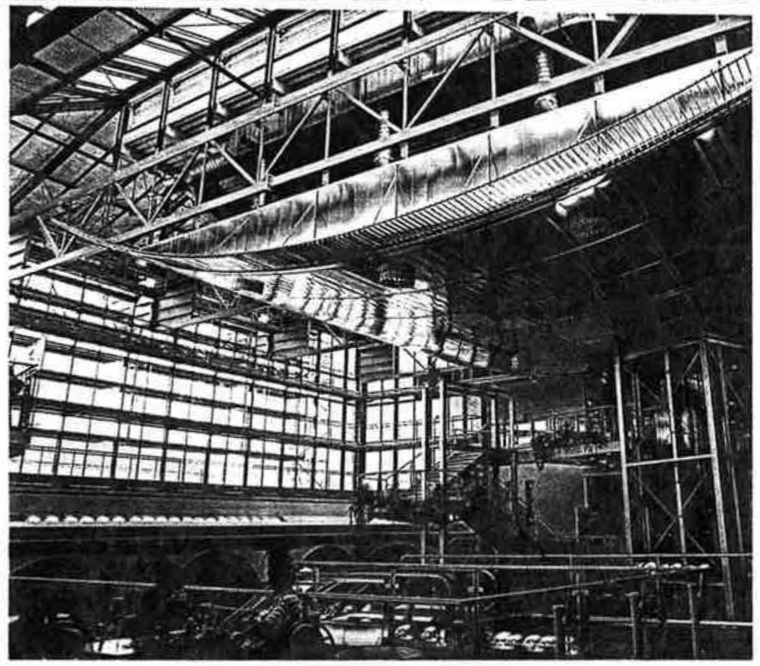
A few actual examples will now be given, showing the different focal points but also the limitations of simulation.

ALTERNATIVES LEAD TO IMPROVEMENTS

Three years ago an office building was erected in Barcelona (Spain) for Laboratorios Almirall S.A. with four basements, ground floor, six office floors and a roof floor. Of these, selected office rooms, a mezzanine, the restaurant and the entrance were investigated by numerical simulation. To optimize the air distribution, for each of these rooms the air velocity pattern, flow direction, air temperature and air renewal were determined for summer (outdoor temperature 31 °C) and winter (outdoor temperature 0 °C) conditions. Typical of the numerous variants was the staff restaurant on the ground floor (Fig. 3■). Figure 4■ shows the simulation of the winter case. At floor level the air velocity reaches 0.5 m/s with a temperature of 19 °C. The temperature below the ceiling rises to 26.5 °C. Under these conditions the situation inside the room is unsatisfactory. Accordingly the original design was modified by placing additional air convectors before the window wall. The result of the second simulation is clear: the convectors spaced over the entire window wall do in fact prevent any cold air downdraught accompanied by pronounced thermal stratification in the room. By eliminating the cold downdraught the air velocities are lowered, which means more comfort here. Through the better distribution of temperature and air velocity, the energy input was also reduced significantly.



4■ *Simulation of air flow in the restaurant in winter. The flow pattern in the cross section shows a temperature difference of 7 K.*



5■ *View into the atrium with the central air treatment unit on a supporting structure under the dome. The supply air flows down through air outlets in order to avoid spreading smells.*

ATRIUM VENTILATION – A DEMANDING TASK

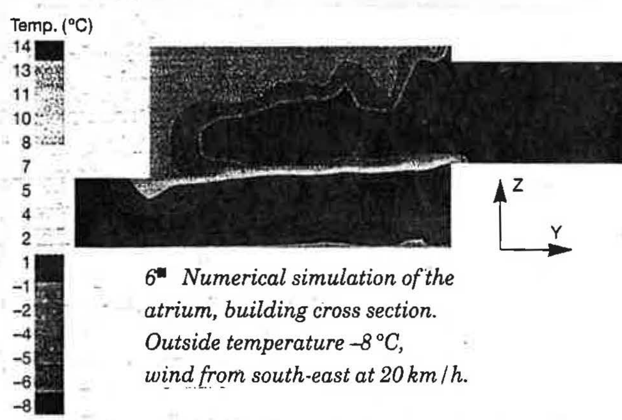
No less convincing than the Spanish example is the "Meiselmarkt" built by the Wiener Städtische Versicherung AG in Vienna. Part of this building was erected over 100 years ago as a storage reservoir and pumping station for the water supply. Today it serves as a market hall. Modern technology has been teamed with monument preservation, for since 1995 the valuable old dome and valve room have been roofed together with the new Meiselmarkt district centre in a glazed atrium with a glazed dome to make use of the natural light (Fig. 5■). Ventilation was rendered difficult by the uncontrolled ingress of outside air through the numerous entrances, propagation of heat and smells at the market stalls, heat accumulation, cold air downdraughts and condensation in the dome.

Detail design and execution of the building services was entrusted to Sulzer Infra Anlagen- und Gebäudetechnik GmbH. To bring down the investment and operating costs, new solution proposals were worked out with the help of numerous numerical simulations. As an example, at the north-west entrance on the ground floor and the south-east entrance in the basement investigations were carried out as to how the air flow and the spread of smells inside the building would be influenced by the wind (Fig. 6■).

The simulation results led ultimately to the ventilation equipment being divided into two units in order to achieve economical operation. By using the water reservoir of the fire protection facilities as energy accumulator for the chilling plant, it was possible to manage without a refrigerating machine – and this means something with a heat demand of 2600 kW and a refrigeration demand of 800 kW Ω

FOR MORE DETAILS

Sulzer Infra Lab AG
Peter Kofoed
Zürcherstrasse 46
CH-8401 Winterthur
Switzerland
Telephone +41 (0)52-262 47 45
Fax +41 (0)52-262 00 02
E-mail sinfra@dial.eunet.ch



6■ *Numerical simulation of the atrium, building cross section. Outside temperature –8 °C, wind from south-east at 20 km / h.*