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Researching air movement

Paul Appleby visited the Roomvent 90 conference in Oslo and discovered the state of the art in room air movement. Here he outlines the papers of immediate value to the building services designer.

oomvent 90 was the second in a series of international conferences on engineering aero- and thermodynamics of ventilated rooms, first held in Stockholm in 1987. Although primarily a Scandinavian event, papers and delegates had a truly international flavour, with six papers from Japan, three from the USSR and France, five from Poland and Britain, and two each from China, Portugal, Canada, Holland, Belgium, Switzerland and the USA. However, there were 27 papers from the Scandinavian countries.

This series of conferences is the main forum for presenting the latest results of research into room air movement and associated topics. In all, 67 papers were presented under the headings of numerical simulations, measurements of velocities, temperature and contaminants, measurements of efficiency, field studies, and full-scale tests and design.

Although much of the work was primarily concerned with advancing research, it is worth outlining those areas which are of immediate use to the building services engineer.

Professor Ole Fanger of the Technical University of Denmark gave one of the opening lectures. He has developed a new method for determining the required ventilation rate in a space. He claims that this method accounts for all (odorous) pollutant sources in a building, and not only those associated with human activities.

Fanger has adapted the simple dilution equation for calculation of ventilation rate, replacing pollutant emission rate with total pollution load in olfs, and indoor and outdoor concentrations with perceived odour level in decipol. Hence:

$$Q_c = 10 \frac{G}{C_i - C_o} \frac{1}{\epsilon_v}$$

where Q_c is the ventilation rate required for comfort in litres/s, G is the total pollution load in olfs, C_i is the perceived desired indoor air quality in decipol, C_o is the perceived outdoor air quality in decipol and ϵ_v is the ventilation effectiveness.

The olf and the decipol are units which have been developed by Fanger; the olf being the odour emission from a standard person and the decipol the perceived air quality in a space with a pollution strength of 1 olf diluted by 10 litres/s of clean air.

Fanger gave typical olf loads of existing buildings, based upon surveys carried out by trained panels of "sniffers" in Copenhagen. He also gave a design range of 0·05 to 0·1 olf/m^2 for low olf buildings, which, he suggests, should be used for all new buildings. This can only be achieved by the systematic selection of low pollution materials for building, including furnishing, carpets and ventilation systems. He also gives olf loads for human activities which can be added to building loads.

A high air quality outdoors is equivalent to a perceived odour level below 0·1 decipol, whereas some towns may have odour levels greater than 0·5 decipol. However, a design level to achieve a maximum 20% dissatisfaction is given elsewhere as 1·4 decipol.

There were 14 papers which reported studies on various aspects of displacement ventilation, and a number of them were of interest to designers.

Melikov and Langkilde from the Technical University of Denmark have undertaken extensive trials of existing displacement ventilation systems. The paper presented was one of a series on this project. It reported the results of their investigation into air movement at floor level, and the potential for discomfort arising from draught and temperature gradient.

They categorised low velocity air terminal devices as either low or high induction, depending on the initial velocity profile. High induction devices had much larger variations in initial velocity over the supply area than low induction devices.

Melikov and Langkilde found that high induction devices created more potential draught problems than the others. They defined a zone close to the device, which should not be occupied on a long term basis by sedentary occupants, as a zone within which more than 15% of occupants would complain of draught.

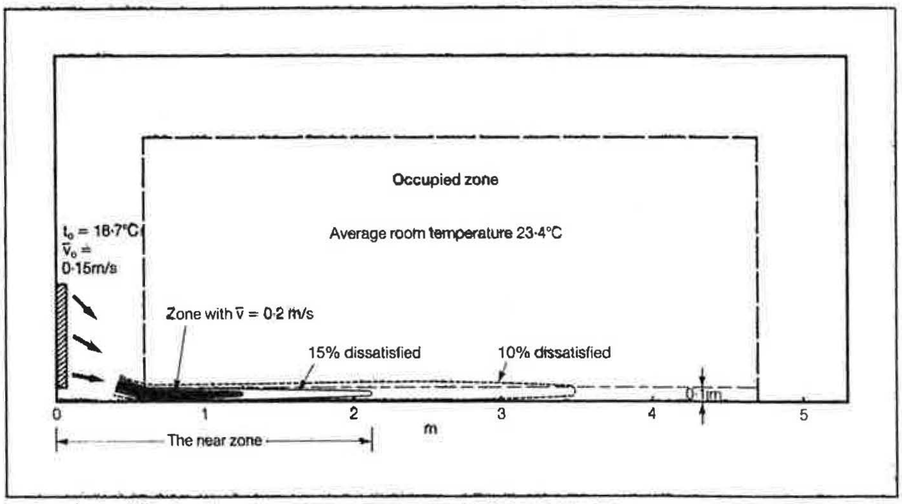
This zone is usually termed the near zone, and the researchers found this to be typically within the region of 0·1 m from the floor, ie at ankle level. They also found that it penetrated into the room at least twice the distance of the 0·2 m/s isovel, the previously defined limit for the near zone (figure 1).

In the 12 rooms investigated, all but one had near zone depths which penetrated more than 0·2 x the room depth. Indeed, one had a near zone extending the full depth, and half the rooms had near zones across half their depth or more.

The authors, probably wisely, did not draw any conclusions about the suitability of displacement ventilation for air conditioning in low ceiling applications. However, this study pointed out some problems with the way in which existing systems in Denmark have been designed.

Holmberg and his co-workers from Flakt Klimprodukter AB of Sweden, and Nickel of Lindab-Riscano of Denmark examined another important aspect of displacement ventilation, namely its alleged ability to create a better quality of inhaled air than is possible with jet-driven high level supply systems.

Holmberg found that, with displacement ventilation, inhaled air is up to eight times cleaner than the air at the same level some distance from the body. This is because inhaled air is partly drawn from the convective plume which is generated by



Above, figure 1: Section through a typical room with displacement ventilation as surveyed by Melikov & Langkilde. This shows different penetrations of zones of v = 0·2 m/s and PD = 15% and 10%.

body heat. If the body is stationary, inhaled air is up to three to eight times cleaner, whereas if the body is seated but moving, inhaled air is two to two-and-a-half times cleaner.

These results were obtained with a supply air rate of 100% outdoor air equivalent to 10 litres/s/person, which is less than the volume required to feed the plume generated by a seated person (given in Flakt literature as 15 to 20 litres/s/person.

While Holmberg used a tracer gas and took measurements of the concentration in inhaled air, as well as the room, Nickel focused on the distribution of carbon monoxide associated with tobacco smoke released from cigarettes left burning in ashtrays, in a simulated meeting room.

Nickel compared the resultant indoor air quality in a meeting room in which cigarettes were burning in ash trays under the following ventilation configurations: supply from either a high level diffuser or floor-mounted low velocity outlet, with exhaust located either at the centre or the edge of ceiling (see figure 2).

Concentrations of CO measured at a height of 1·2 m, at a position on the opposite side of the meeting table from the ashtrays, were found to be lowest with the displacement ventilation arrangement. Concentrations were lower for both methods of supply when combined with an exhaust located in the centre of the room. The researchers noted a significant rise in concentration after a worker entered the room and disturbed the stratification associated with displacement ventilation.

Nickel concluded that air quality could be quite acceptable for non-smokers seated along one edge of a meeting table and smokers along the opposite edge, as long as exhaust openings were provided in the ceiling between them, particularly with displacement ventilation systems.

Braun of Geilinger, Switzerland, described full-scale tests and a computer simulation of the performance of a displacement ventilation system using a thermal store. The building had a well-insulated perimeter, incorporating Geilinger's high insulation windows, having a U-value of 0·65 W/m^{2}K. The displacement system had room or individual controls with a supply flow rate varying between one and five air changes/h, but with no mechanical cooling.

One rather unusual aspect of the system control was that the ventilation system was switched off when the outside temperature exceeded 22°C, above which occupants could open windows. Fans could be run at night to cool the building mass.

Measurements were taken over a whole year and an accurate computer simulation model was developed. This showed that, on a hot Friday, with a peak gain of 50 W/m^2, and outside temperature varying from 15°C to 35°C, the room temperature varied from 25°C at 0800 h to 27·5°C at 1700 h. Predictions for a system with ordinary openable double glazed windows and natural ventilation showed temperatures of 27·5°C to 31·5°C for the same day.

18 papers were devoted to numerical simulations. These have become ever more powerful in recent years as computers have become faster and techniques more efficient and finely tuned. Many of the papers demonstrated research tools, some of which were validated against full-scale chamber measurements.

Holmes and his colleagues from Arup Research and Development in the UK carried out a full transient coupling of two-dimensional dynamic thermal modelling and computational fluid mechanics codes. Their paper described how this combination was used to model conduction, convection and radiation in a perimeter office served by a constant volume air conditioning system with reheat coil.

They were able to use the model to predict instability in the control of the reheat coil, the operation and control of which was also modelled. Their results indicated that, during a two hour period on a winter's morning, the supply temperature oscillated with increasing amplitude under the dictates of a room temperature sensor, followed by a similar oscillation in room air velocity caused by varying convective flows. Unfortunately, this was not validated against a physical model.

The run time on an 8 Mbyte processor was more than six-and-a-half hours, much of this time being taken up with second-by-second computational fluid dynamics analysis.

The next Roomvent conference will be on 2-4 September 1992 in Aalborg, Denmark. Contact Professor Peter Neilsen for more details at AUC Denmark, Sohnen gaardsholmvej 57, DK 9000 Aalborg, Denmark.

For a copy of the proceedings of Roomvent 90, contact Skarland Press A/S, PO Box 5042 Maj, N 0301 Oslo 3, Norway.

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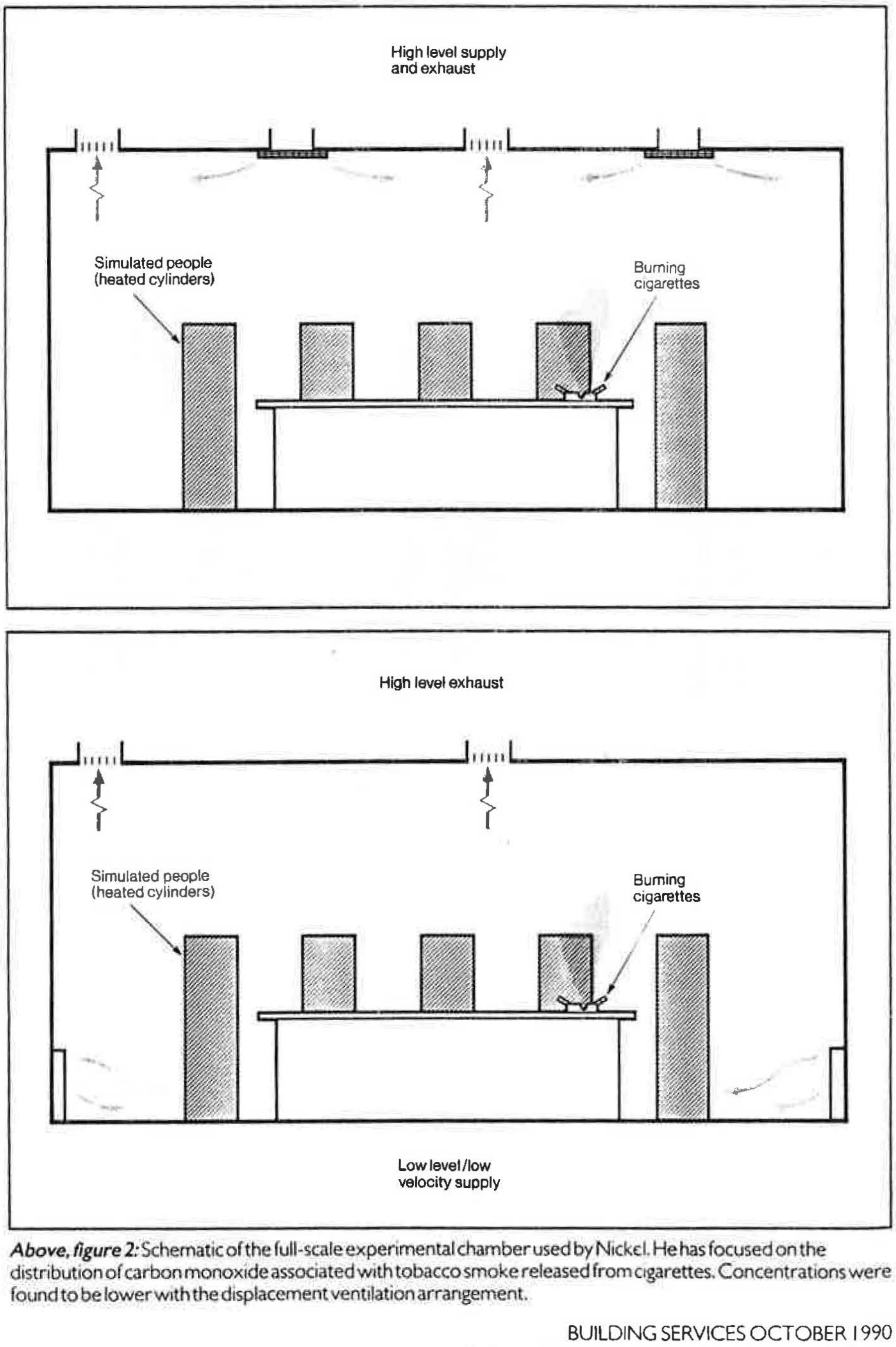

Above, figure 2: Schematic of the full-scale experimental chamber used by Nickel. He has focused on the distribution of carbon monoxide associated with tobacco smoke released from cigarettes. Concentrations were found to be lower with the displacement ventilation arrangement.