MEASUREMENTS OF VENTILATION PERFORMANCE IN A RETROFITTED CONFERENCE ROOM.

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ABSTRACT

The ventilation system of a 60 seats conference room was retrofitted to improve indoor air quality. The old, mixing type installation was replaced by a displacement ventilation system. However, the building layout did not allow an optimum location of air inlets and outlets. It was therefore interesting to measure the actual performance of the new system.

Using tracer gas techniques, the age of air was mapped within the room, and the ventilation effectiveness was measured in various configurations. The actual air flow rates were also measured in the ventilation system. Configurations were: empty room, room occupied by immobile, heated artificial bodies, and room with real occupancy.

The air change efficiency was found unsatisfactory, and recommendations were given to improve it. The ventilation system was modified, the room was made more airtight, and measurements were performed again, which proved the efficiency of these modifications.

The contribution presents the experimental planning, the results, and the practical conclusions, which can be deduced from this experiment.

KEYWORDS

Ventilation, efficiency, measurement, tracer gas, age of air.

INTRODUCTION

Efficient ventilation aims to bring fresh, new air to the occupants. Displacement ventilation was developed to improve air change efficiency, i.e. to develop a flow pattern such that the age of the air increases continuously from floor to ceiling, and where fresh air is brought mainly around persons and other heat sources [Skåret, 1985 and 1986].

Such system is not simple to apply. On one hand, moving heat sources and bodies tend to mix the masses of air and to destroy the flow pattern. On the other hand, it is not straightforward to install inlet and outlet grids at ideal locations, when account is taken of the other conditions required by the use of the room. It is particularly difficult to apply displacement ventilation in an existing room with natural ventilation or equipped with a classical full mixing ventilation system.

METHODS

Measuring the age of air

The concept of age of air is used since several years to quantify ventilation performance [Sandberg and Sjöberg, 1984].

Tracer gas techniques are used to measure the air change efficiency [Roulet and Vandaele, 1991]. The principle is as follows: at time t_0, the injection rate of a tracer gas in the main inlet duct is abruptly changed (e.g. in a step up from zero to a given rate, in a step down, or in a pulse). At any location in the room, the change in tracer gas concentration is an image of the distribution of the age of the air marked by the tracer. Analysing samples in the exhaust duct provides the room mean age of air, $\bar{\tau}$, the nominal time constant, τ_n (which is the inverse of the air change rate), and the air change efficiency defined by:

$$\eta_v = \frac{\tau_n}{2\bar{\tau}} \quad (1)$$

The air change efficiency is 1 (or 100%) for perfect piston ventilation, 50% for complete mixing and smaller than 50% when there are dead zones or short cuts in the air flow pattern.

Mapping of the age of air

A two or three-dimensional map of the age of the air can be obtained by measuring the evolution of the tracer concentration at various locations in the room. Since heat sources are of importance in displacement ventilation, measurements should be performed with simulated - or preferably real - occupancy.

Accurate mapping with real occupancy requires a large number of simultaneous samples in the room. For cost and technical reasons, it is impossible to multiply the measurement points beyond a given limit. Therefore, a compromise should be found between the accuracy of the map and the cost and feasibility of the measurements.

The methodology of experimental planning [Box, Hunter and Hunter, 1978] is of great help in the choice of the location of the sampling points. It allows to locate a minimum number of points in such a way that the parameters of the map are obtained with the best possible accuracy. Such a method was developed and tested [Roulet and Compagnon, 1990] on an experimental room and is described in [Roulet and Vandaele, 1991]. It is however the first time we used it with actual occupancy to check the ventilation performance of a real-world displacement system.

Our material includes a non-dispersive infrared spectrometer and a pump and valves system allowing sampling the air at up to ten locations. For this reason, nine sampling points were located in order to obtain the best accuracy for the pa ameters of a second degree function describing the map of the age of the air, τ, as a function of space variables x_1, x_2, x_3:

$$\tau(x_1, x_2, x_3) = a_0 + \sum_{i,j} a_i x_i + a_{ij} x_i x_j \quad (2)$$

Where a_i and a_{ij} are coefficient to be determined. The tenth point was used to monitor the concentration in the exhaust duct.

Description of the room

The conference room is 8 by 10 m wide and 3 m high (Figure 1). It is completely embedded in an old, massive building. Its walls, floor or ceiling have no contact with the outdoor environment. It has no windows, but untight entrance doors leading to a hall.

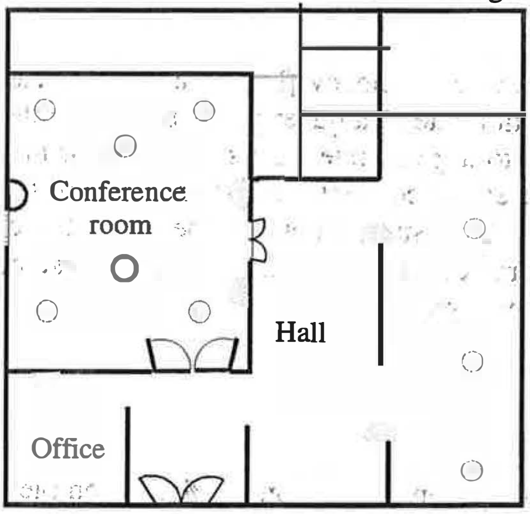

Figure 1: Sketch of the conference r om and its surroundings. After a first set of measures, new inlet and exhaust grids were installed, and leaky passages to the rest of the building were walled up.

The original displacement ventilation systems includes two low velocity air inlets, one meter high, put at the floor level against one wall of the room. This asymmetric disposition does not allow a uniform distribution of fresh air in the room, but was first adopted for practical reasons. Five exhaust grilles were installed in the ceiling. The mechanical ventilation system maintains the conference room under pressure with respect of the surrounding spaces. However, because of the untight doors, the air flow rate varies when doors or windows are open or closed in the surrounding spaces.

RESULTS

Global effect of system improvements

First measurements have shown a relatively poor distribution of the air in the room, a third inlet grid was placed against the left wall of the room, and a new exhaust grid was installed in the ceiling, in order to improve the air distribution in the room (see Figure 1). Leaky doors to a neighbouring building, strongly perturbing the air distribution, were also walled-up or made airtight.

New measurements were performed after this improvement to observe its effect. The effects of improvements on air change efficiency are clearly shown on Table 1 . The poor air change efficiency measured in original room was greatly improved, thus providing the required age of air with much lower airflow rate.

Table 1: Age of air at exhaust and air change efficiency

	Initial values		After improvement		
	Empty	Occupied	Empty	Occupied	Unit
Mean age of air in conference room	380	480	420	350	s
Nominal time constant	240	380	620	580	s
Air change rate	15	9.5	5.8	6.2	/h
Air change efficiency	30	40	74	81	%

Effect of occupancy

The effect of occupancy was first observed in the original room, before improvement. A first measurement was performed in the empty room, with sampling points arranged for a three-dimensional mapping as shown on Figure 2. A second experiment was performed with simulated occupation. Six persons were simulated by six 100 W light bulbs, each contained in a 70 l plastic bag. A heated mannequin simulated a seventh person. These sources were put on chairs at tables, as shown on Figure 2.

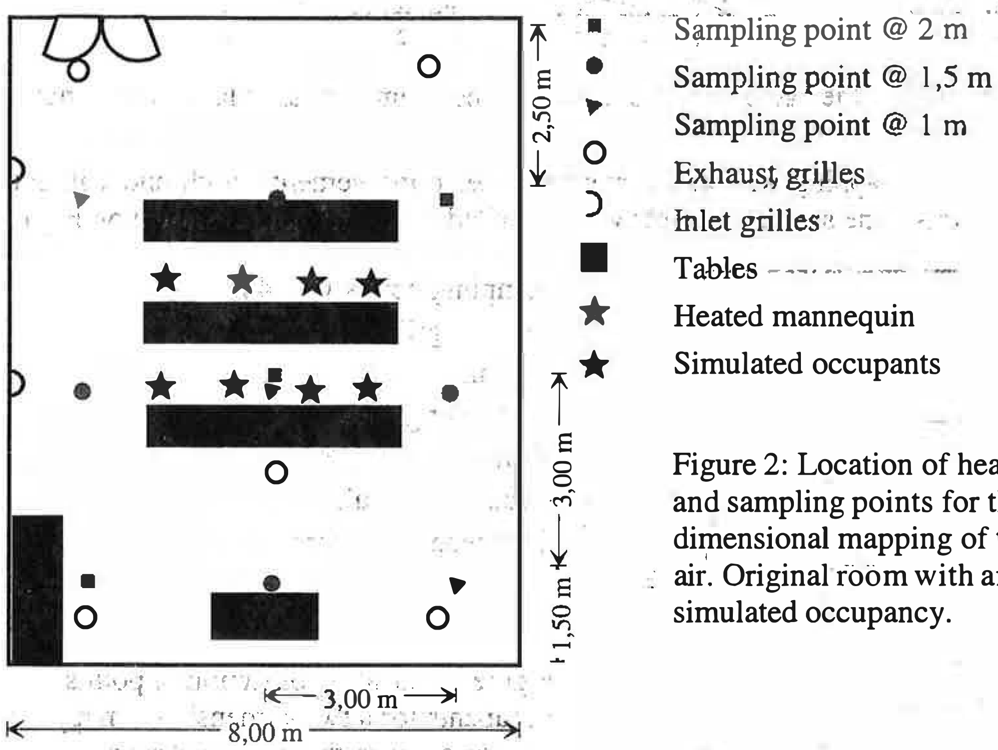

Figure 2: Location of heat sources and sampling points for three-dimensional mapping of the age of air. Original room with and without simulated occupancy.

The ages of air measured at sampling points ranged from 330 to 520 s. The maps in Figure 3 clearly show the asymmetry in the distribution of the air, the right-hand side getting an older air than the left-hand side, closer to the air inlets. This experiment does not put in evidence any significant change with height. This may result from the absence of heat sources. It should be mentioned that the high age shown in the bottom right corner is extrapolated and therefore less accurate than the ages shown at the sampling points.

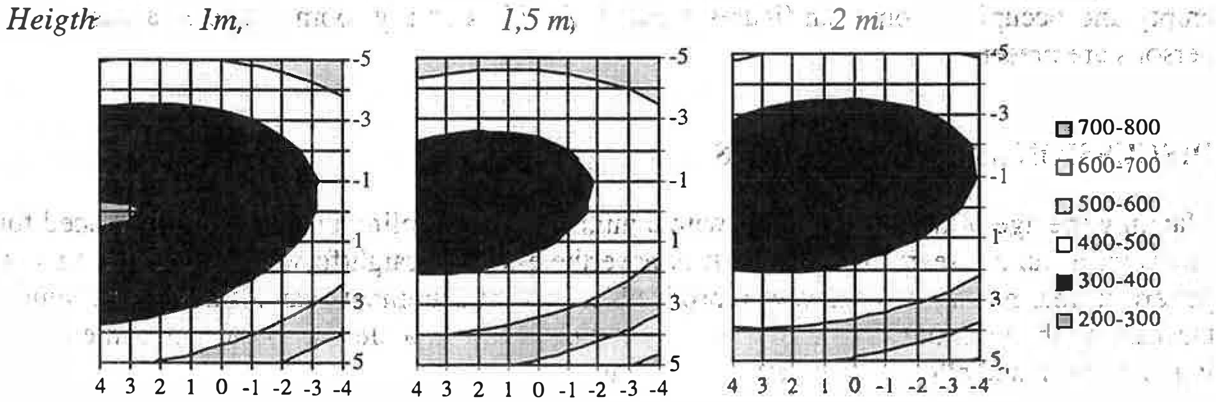

Figure 3: Maps of the age of air (in seconds) in the empty room. Maps on Figure 4 show the results with ar ificial occupancy. The age of the air increases significantly between 1 and 2 m high. The asymmetry and dead zones nevertheless remain.

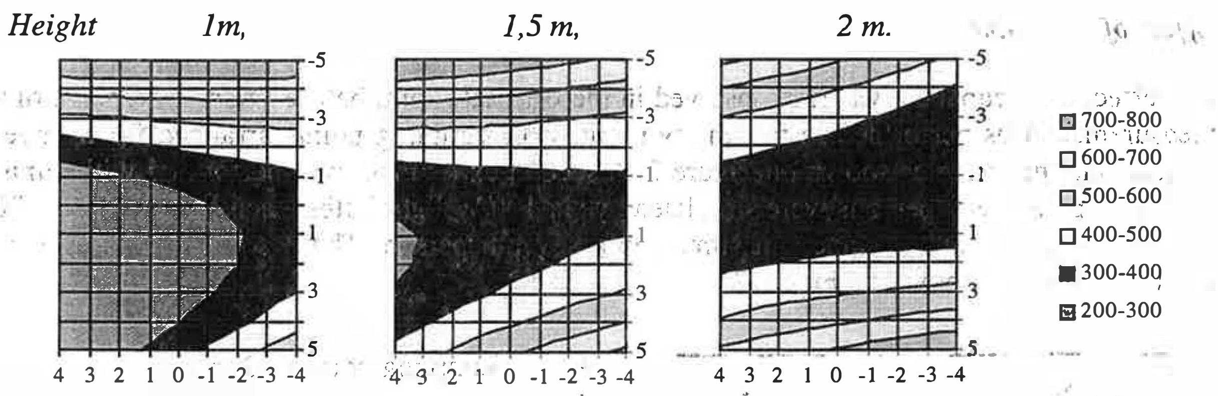

Figure 4: Maps of the age of air (in seconds) in the room with simulated occupancy.

A two-dimensional mapping was also performed after improvements, with and without real occupancy. For this, nine sampling points were installed at 1,4 m high, as shown on Figure 5.

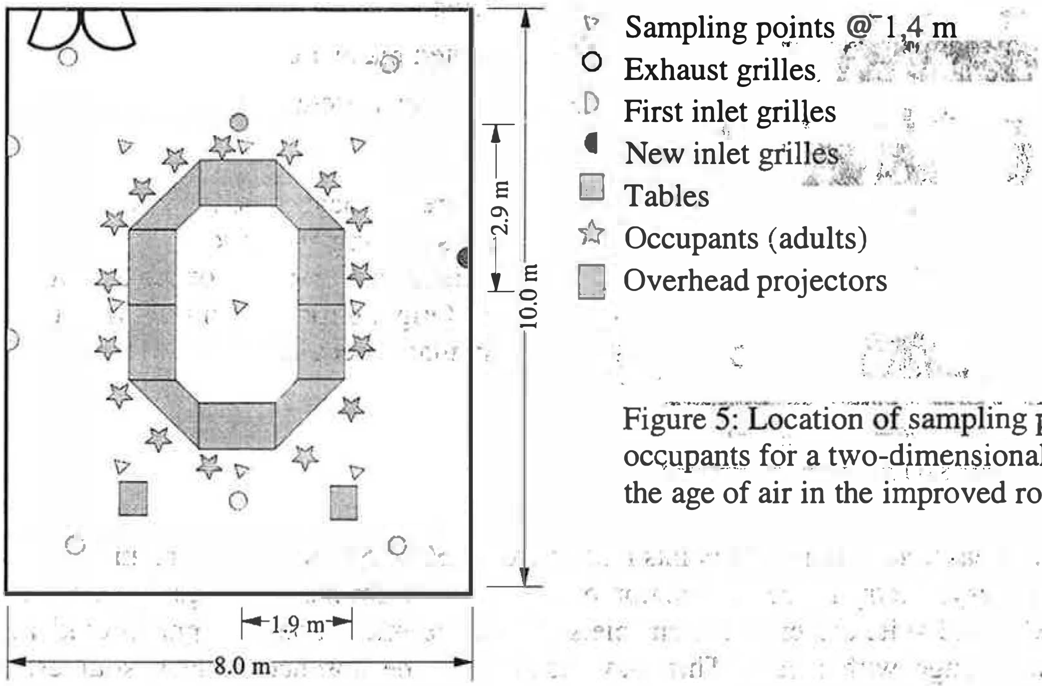

Figure 5: Location of sampling points and occupants for a two-dimensional mapping of the age of air in the improved room.

The maps resulting from these measurements are shown on Figure 6. The pattern is more symmetric than before improvement. These maps show the same change in shape between empty and occupied room than figures 3 and 4: A hill in empty room becomes a pass when persons are present.

DISCUSSION AND CONCLUSIONS

Mapping the age of the air in a room with a minimum of sampling points carefully placed for optimum accuracy seems promising. It is nevertheless not straightforward, since the airflow pattern in real rooms is not always reproducible, and measurements cannot always be simultaneous. In the present case study, me surement have shown a cle r dysfunction in the ventilation system, and llowed to greatly improve it.

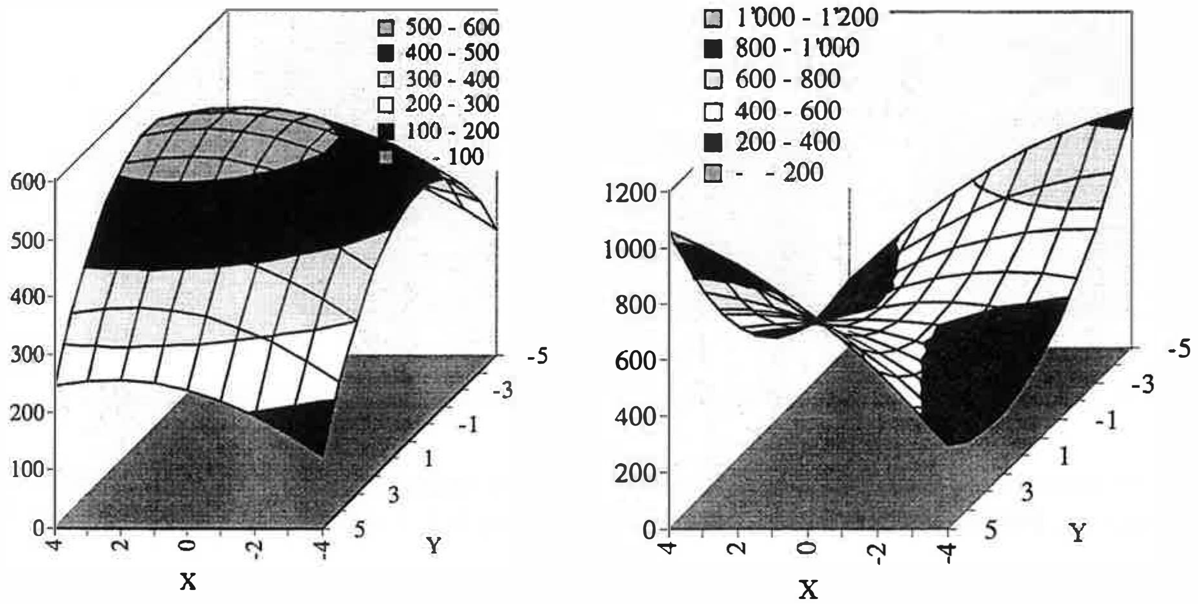

Figure 6: Map of the age of air in the improved room, at 1,4 m high. Left: empty room; right: room occupied by 16 persons. Age of air is in seconds on vertical axis.

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