VENTILATION BY DEMAND

Finn Drangsholt, MSc Engineer

SINTEF, Division of Applied Thermodynamics, Trondheim, Norway

Abstract

In buildings where the main source of pollution comes from people, CO2 from respiration can be used as an indication of the air quality.

This paper considers the potential savings which can be made when the amount of fresh air is controlled in accordance with the measured concentration of CO2 in the occupation zone. The paper also discusses some of the practical problems connected with the introduction of this type of control strategy.

Selection of CO2 level

Ventilation plants today are normally dimensioned to the maximum number of people the building is designed for and there is no possibility of adjusting to varying personnel loads, activity levels and infiltration.

It is obvious that considerable savings are possible in buildings with a great variation in personnel loads, if instead of providing a constant amount of fresh air, the air quality in the occupied zones is kept within stated limits.

The connection between the concentration of CO2 and the intensity of body odour in a room has been studied for a number of years at The Technical University of Denmark. These investigations have enabled a comparison to be made between body odour and the concentration of CO2, see Figure 2.1. A second comparision is also made on the basis of these investigations, the percentage of dissatisfaction and the CO2 concentration in a room, Figure 2.2.

The Danish experiments were conducted by a panel of judges visiting the test room under different personnel loads. Subjective assessments of the level of odour were made and quantified in relation to a given scale, evaluations of whether the level of odour was considered acceptable or not were also made.

As Figure 2.2 shows, 20% of the visitors found CO2 levels of upto 1000 ppm acceptable.

Potential energy savings with CO2-controlled ventilation

The CO2 concentration in the outlet air was registered in various buildings during a three week period to determine the potential energy savings CO2-controlled ventilation would represent. Figure 3.1 shows examples of the development of such concentrations.

These registrations were used as input data in a model to simulate the energy consumption in a building during the course of the year. Complete mixing of the ventilation air in the premises was assumed in these calculations.

The calculated difference in the annual energy consumption with and without CO2-control represents the potential energy savings. Figure 3.1 gives the results of these calculations for 10 different localities.

The figure clearly shows that it is possible to achieve upto a 50% reduction in energy consumption. The size of the reduction depending on the energy savings measures which were in effect before, and the variation in the personnel load in relation to the dimensioned values.

Experiments with CO2-control

Practical experience with the CO2-control was obtained by equiping an auditorium with space for 500 students with CO2-controlled ventilation.

Figure 4.1 illustrates the principle behind the ventilation plant in the auditorium.

Prior to starting the experiments, the CO2 concentrations in the auditorium were registrated at three points as well as in the outlet during a five day period. Then the auditorium was experimentally controlled by modulated recirculated air from a CO2 reference in the outlet which was set at 700 ppm.

Figure 4.2 shows the development of the CO2 concentration during two similar days with and without CO2-control. The diagrams indicate that the curves developed in a similar manner during the course of the day, even though almost 80% of the air was recirculated in one case.

It was concluded from these experiments that the CO2 concentration in the auditorium was not adequately controlled.

It was decided to investigate how effectively pollution was removed from the auditorium in order to determine why this control did not function as it should have.

The answer to this was given by following the CO2 concentrations in the outlet from the moment teaching started until stationary conditions were obtained. This development is shown in Figure 4.3.

There is however a problem that stationary conditions did not occur during the 45 minute lecture, consequently we had to "predict" part of the concentration development.

This development can be described by the expression:

$$C(t) = C_\infty(1-e^{-\lambda t})$$

$C(t)$ = concentration at time specified

C_∞ = concentration with stationary conditions

$1/\lambda$ = turnover-time for pollution

In this expression C_∞ and λ were unknowns, whilst the concentration development (t) was known part of the time. C_∞ and λ can be calculated by means of a regression analysis for non-linear systems of equations.

When the turnover-time for the pollution and the cubic volume of the fresh air supplied are known, the ventilation efficiency of the system can be calculated. This is given by the equation:

$$\varepsilon_v = \frac{VR/\dot{V}}{2 \cdot (1/\lambda)}$$

Table 4.1 gives the results of these calculations for three different load situations:

Table 4.1

Personnel load	Turnover time for pollution $1/\lambda$ (min)	Ventilation efficiency $\langle\varepsilon_v\rangle$
50	14	0.28
120	24	0.23
180	27	0.20

As the table shows the ventilation efficiency declined with rising personnel loads. In a room with complete mixing the ventilation efficiency is $\langle\varepsilon_v\rangle = 0.5$, i.e., in this case there is a considerable amount of short-circuiting between inlet and outlet air. The degree of short-circuiting is also dependent upon the personnel load. Figure 4.4 gives a outline of the flow situation in the auditorium.

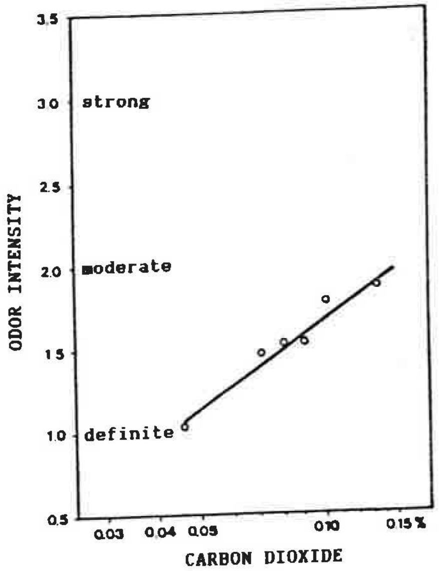


Fig. 2.1 Odor intensity as a function of CO_2 consentration.

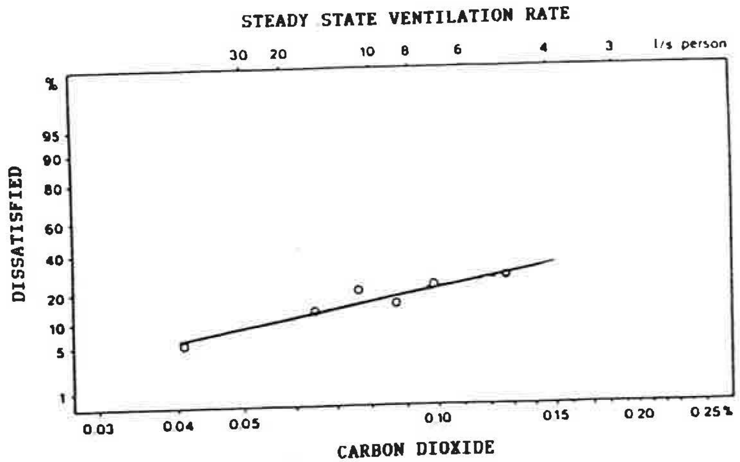


Fig. 2.2 Percentage of dissatisfied as a function of the CO_2 consentration.

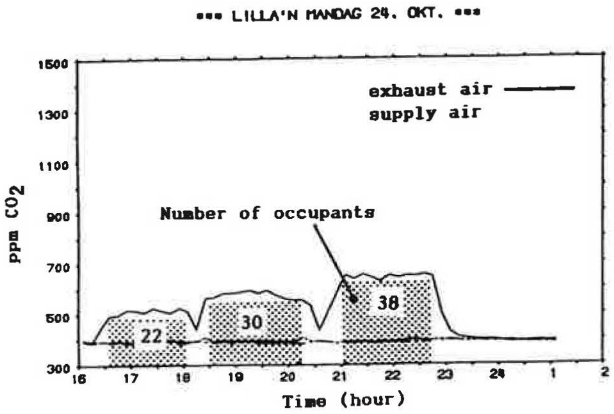


Fig 3.1
CO_2 consentration meassured in the exhaust air.

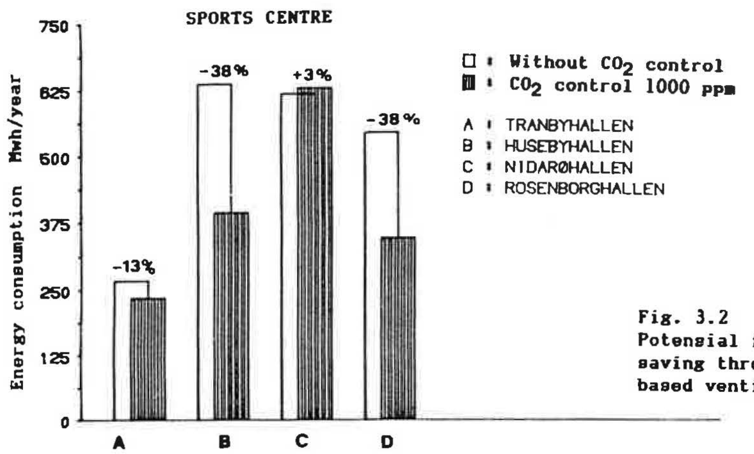
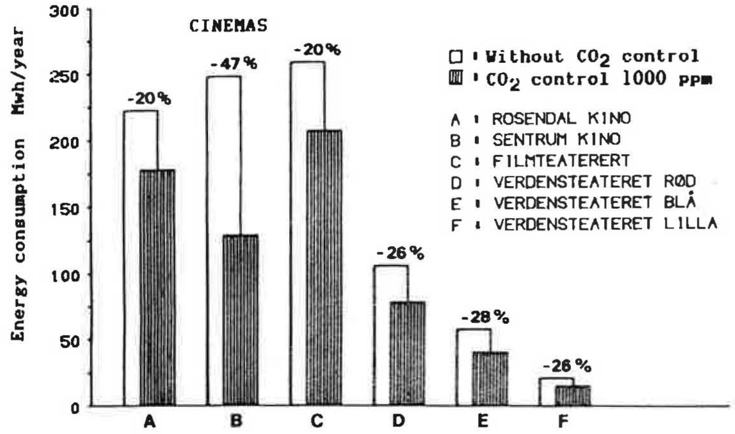


Fig. 3.2
Potensial for energy-saving through CO_2 based ventilation.



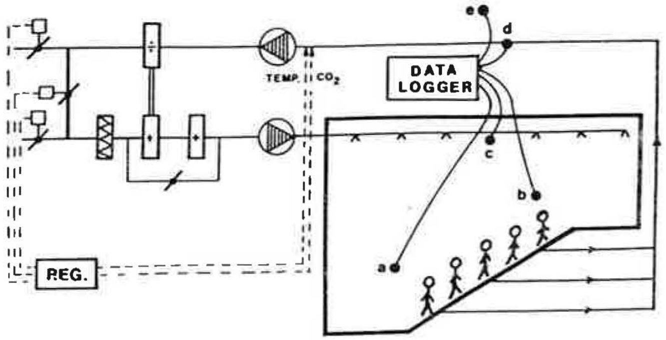


Fig. 4.1 Sketch of ventilation system and control system for the auditorium

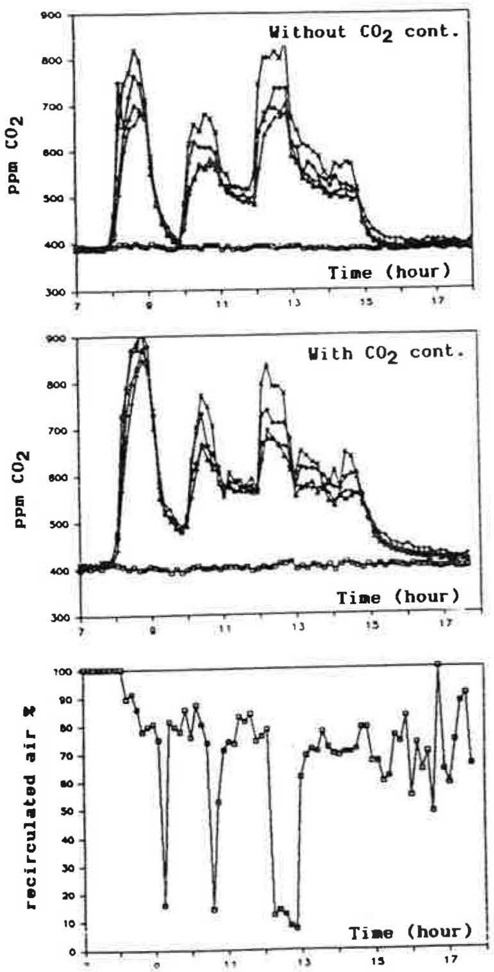


Fig. 4.2
CO_2 consentration in exhaust air, with and without CO_2 control.

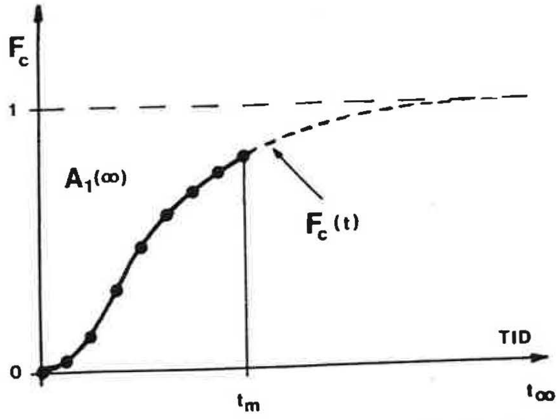


Fig. 4.3 CO consentration in exhaust air at constant of occupants.

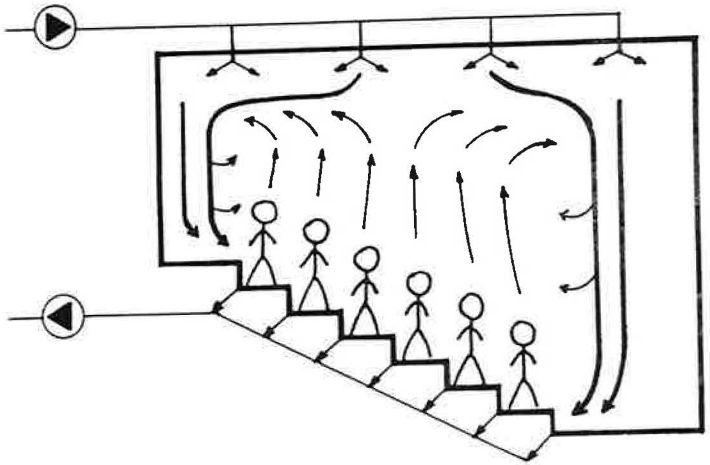


Fig. 4.4 Air flow pattern in the auditorium.

CHARACTERISTICS OF CONCENTRATION CHANGES IN A CLEAN ROOM

Shuji Fujii and Elisa C. Boelman
Tokyo Institute of Technology, Tokyo, Japan

ABSTRACT

This paper discusses a set of experiments aimed at investigating the influence of various parameters upon the characteristics of particulate concentration changes in a conventional airflow clean room. Indoor particulate concentration decrement factors were determined for various locations and used to determine the time needed for concentration to stabilize and the particulate removal efficiency at each location.

INTRODUCTION

The research presented in this paper focuses on the characteristics of particulate concentration changes at various locations in a conventional airflow clean room. The influence of parameters other than the rate of clean air supply is investigated and discussed in terms of indoor concentration levels, particulate concentration decrement factors and particulate removal efficiency.

ANALYSIS

The ability of clean room to "clean up" can be expressed in terms of its number of room air changes. Non-uniform flow patterns wwithin the room, however, may cause differences in the concentration characteristics at different locations. In this paper, Indoor Particulate Concentration Decrement Factor, Time to reach the steady-state condition and Particulate Removal Efficiency are used to assess the influence of location and other conditions upon concentration changes in a conventional airflow clean room.

Assuming uniform particulate diffusion and no particulate generation, adhesion or settling in the room, concentration $C_{(T)}$ at time T is given by

$$C_{(T)} = C_o \times e^{-N \times T} \qquad (1)$$

where C_o is the room average initial concentration (particulates/m^3) and N the number of air changes in the clean room (times/h). (2,3)

If local (i.e. for each measuring point) concentration values are used instead of room average ones in Eq.(1), "local" numbers of air changes (N_{local}) may be determined for various locations in the room, from the slopes of their respective concentration decrement curves (Fig. 4). These "local numbers of air changes" are termed Indoor Particulate Concentration Decrement Factors, **Df** and are calculated as (1)