IMPROVED INDOOR AIR QUALITY BY SUPERVISION OF THE CO_2 CONTENT

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This article presents a number of examples of how the supply of outdoor air to a room can be adapted on the basis of the measured content of carbon dioxide in the indoor air, so that an acceptable air quality will be maintained in the room. The results of studies carried out in a conference room, three offices and a school are reported. The measured values of carbon dioxide contents were employed both for controlling the outdoor air flow and for checking that the ventilation systems operate satisfactorily.

INTRODUCTION

In many premises, continuous measurement of the carbon dioxide content can provide valuable information on the quality of the indoor air. This information can then be used for controlling the supply of outdoor air, or for determining how the air quality varies with different operating conditions and varying occupant loading. Temporary measurements of the carbon dioxide content also provides a simple means for assessing the air quality at a certain workplace.

Examples of all of the above methods of using the information on the carbon dioxide content of indoor air are presented in this article. An installation in a conference room is described to illustrate how the outdoor air flow is controlled on the basis of the carbon dioxide content in the indoor air. This conference room, which was originally equipped with a temperature-controlled Variable Air Volume (VAV) system, has been equipped with a carbon dioxide sensor that operates in parallel with the temperature sensor.

Some results of continuous monitoring of the carbon dioxide content in office premises are also described. Moreover, the article presents the results of temporary measurements of the carbon dioxide contents in schools in which both a mechanical exhaust air system and natural draught ventilation are employed. These measurements revealed comparatively high carbon dioxide contents.

AIR QUALITY CONTROLLED VENTILATION

Improved air quality is now demanded in many types of premises, which usually involves increased energy consumption for heating, cooling and distributing the ventilation air. By controlling the outdoor air flow rate on the basis of the content of pollutants in the indoor air, i.e. by employing air quality controlled ventilation, good air quality can always be maintained at the lowest energy consumption. Systems for air quality controlled ventilation, often known as demand-controlled ventilation, installed so far have usually employed carbon dioxide sensors for monitoring the air quality.

Ventilation systems of this type are best suited for premises in which the occupant loading varies widely and more or less unpredictably. A prerequisite is also that the air flow rates employed are determined by the pollutants emitted by the occupants themselves, principally in the form of carbon dioxide and odorous substances. Typical premises in which carbon dioxide controlled systems have proved beneficial include auditoria and other large public premises (1, 2). However, such systems have also been tested in other types of premises, such as large offices (3).

Simple carbon dioxide sensors are now available, and it is therefore justifiable to install air quality controlled ventilation systems even in relatively small premises with varying occupant loading. An installation of this type in a conference room designed for an occupant loading of 15 persons is described below in some detail. A comprehensive measurement programme is now in progress in this conference room, with the aim of establishing the quality of the indoor air under different operating conditions and to determine the opportunities available for saving energy. The project is supported by the Swedish Council for Building Research and is included in the IEA programme for demand-controlled ventilation systems (Annex 18).

The conference room has a floor area of 33 m^2 and a volume of 90 m^3, and is served by a Variable Air Volume (VAV) ventilation system. A carbon dioxide sensor (based on the photo-acoustic principle) is located in the vicinity of one of the exhaust air devices in the conference room. The signal from this sensor is supplied to the control unit for the room, so that combined carbon dioxide and temperature control is obtained. The control system is adjusted in such a manner that the output signal from the carbon dioxide sensor begins to control the air flow when the content of carbon dioxide has exceeded 600 ppm.

The measured values of room temperature, carbon dioxide content and supply air flow are shown in Fig. 1 for a working day during which the occupant loading in the conference room varied widely. The temperature of the air supply to the room was maintained virtually constant throughout at around 18.5°C, while the outdoor temperature varied between 10 and 13°C during the period when the ventilation system was in operation, i.e. between 06:30 and 18:00 hours.

As shown in Fig. 1, the rate of air flow supplied to the room increased substantially as soon as the carbon dioxide content exceeded 600 ppm. As a result, the maximum carbon dioxide content is restricted to around 830 ppm, which is less than 500 ppm higher than the content in outdoor air. At maximum occupant loading in the room, the supply air flow is almost 250 l/s. However, the mean value of the supply air flow during the 11.5 hours of operation of the ventilation system was only 100 l/s.

If a Constant Air Volume (CAV) system had been selected instead of a VAV system for ventilating the conference room, it would probably have been rated for a supply air flow of 10 l/s per person, i.e. a total of 150 l/s. The average energy consumption for heating the ventilation air would thus have been higher. In addition, the carbon dioxide contents at the highest occupant loading would have been higher, since the supply air flow to the room would have been restricted to 150 l/s, which is only 60% of the flow supplied by the VAV system. A VAV system controlled by the carbon dioxide content in the indoor air can thus be beneficial both to energy consumption and to the quality of the indoor air.

CONTINUOUS SUPERVISION OF POLLUTANT CONTENTS

The outdoor air flow rate that must be supplied to a building is determined by the quantity of pollutants emitted from various sources. However, the building standards of most countries have long been based on the assumption that the occupants themselves are the principal cause of the most important pollutants. The contents of carbon dioxide and odorous substances have thus been the design parameters.

Considering the example of an office in which the personnel are seated while working, and assuming that outdoor air is supplied at the rate of 10 l/s per person, the carbon dioxide content in the occupied zone will be around 500 ppm higher than that of outdoor air, provided that the air is supplied effectively. By measuring the carbon dioxide content, it is thus possible to control the rate at which the ventilation system supplies outdoor air. If measurements are taken in the occupied zone, assurance will be obtained that the outdoor air reaches the various workplaces.

Since simple means are currently available for measuring and indicating the carbon dioxide content, continuous supervision of the contents in many premises is now fully justifiable. Any shortcomings in the ventilation system can then quickly be corrected. In addition, consciousness of the importance of the indoor climate will probably be enhanced if the carbon dioxide content is monitored.

Aritron type AROX 425A carbon dioxide sensors for continuous supervision of the carbon dioxide content were installed in two offices adjacent to the conference room described above. Each of these offices has a floor area of 180 m^2, and they are both ventilated by a temperature-controlled VAV system. In addition to the carbon dioxide content in the premises, the supply air flows and the supply air and room temperatures are recorded in the current test programme. The data obtained has provided the basis for suggesting modifications to the two ventilation systems.

Fig. 2 shows the measurement results from a single-occupant office and illustrates that faults in a ventilation system can quickly be detected by continuous supervision of the carbon dioxide content in the indoor air. In one of the two cases shown, the ventilation system (VAV system with a supply air flow of 10 - 40 l/s) was in normal operation, whereas in the second case, the ventilation system had been inadvertently shut off. The substantial increase in the carbon dioxide content in the latter case indicates that the contents of hygienically hazardous pollutants from the building materials, interior fittings and furniture have also increased by a corresponding amount.

TEMPORARY MEASUREMENTS IN A ROOM

Temporary measurements of the carbon dioxide content in a room during normal occupancy have proved to provide a simple means for checking that the ventilation system supplies the expected flow of outdoor air and determining whether this air reaches the occupied zone. By comparing the measured content of carbon dioxide with the calculated value, such as that an effective outdoor air flow of 10 l/s per person will result in a carbon dioxide content of around 500 ppm above the content of the outdoor air, a relatively accurate yardstick is obtained of the effective outdoor air flow to the premises. This method of estimating the outdoor air flow may be advisable as a first measure for premises in which problems are experienced in maintaining good quality of the indoor air.

The example of a study undertaken at a school in the Stockholm district is presented below. This particular school consists of two buildings, one of which is ventilated by a mechanical exhaust air system, while the other has natural draught ventilation. Both ventilation systems will be modified to mechanical supply and exhaust air systems with heat recovery. A system based on occupant control will also be tested in a research project supported by the Swedish Council for Building Research.

The carbon dioxide contents were measured comprehensively in some of the classrooms before the ventilation systems were modified. The results of the measurements carried out in a classroom with mechanical exhaust air ventilation are shown in Fig. 3 for varying numbers of pupils in the room. The figure shows that the carbon dioxide content was more than 1800 ppm on one occasion when 26 pupils were present in the classroom. Even higher contents - more than 2000 ppm - were recorded during corresponding measurements in a classroom with natural draught ventilation.

In both of the above cases, the supply of outdoor air to the classrooms is obviously insufficient. It is doubtful whether effective instruction can be pursued in premises in which the air quality is as poor as these measurements would indicate. However, judging by earlier studies (4), unsatisfactory air quality in schoolrooms is by no means unusual.

CONCLUSIONS

The study undertaken shows that the following procedure can be adopted to improve the quality of the indoor air on the basis of knowledge of its carbon dioxide content:

- in premises with widely varying occupant loading, by controlling the outdoor air supply rate on the basis of the carbon dioxide content,

- by continually indicating the carbon dioxide content in the premises, so that any faults in the ventilation system will quickly be detected,

- by measuring the carbon dioxide content temporarily, to check whether sufficient outdoor air is supplied to the premises or to a workplace.

REFERENCES

1. Strindehag, O., Persson, P-G. Auditorium with demand-controlled ventilation (1989). Air Infiltration Review, 10, No. 2, 7 - 9.

2. Drangsholt, F. Ventilation by demand. Proc. of the 4th Int. Conf. on Indoor Air Quality and Climate, Aug. 17 - 21, 1987, Berlin.

3. Södergren, D., Punttila, A. Demand-controlled ventilation. Report R67:1983, Swedish Council for Building Research (in Swedish).

4. Potting, J. et al. Health complaints, CO_2 levels and indoor climate in Dutch schools. Proc. of the 4th Int. Conf. on Indoor Air Quality and Climate, Aug. 17 - 21, 1987, Berlin.