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Long-Term Experience with Demand-Controlled Ventilation Systems

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ABSTRACT

The performance of three demand-controlled ventilation systems has been studied for a period of 1.5 to 3 years. The ventilation systems are installed in an auditorium, a conference room, and a school. In both the auditorium and the conference room, carbon dioxide sensors are used for air quality control, whereas presence sensors of the passive infrared type are used to control ventilation rates in the school. The results of numerous measurements of carbon dioxide concentrations and airflows of the buildings under different outdoor conditions and occupant loads are reported here. The reliability of the control systems is also discussed.

INTRODUCTION

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

Ventilation systems of this type are best suited for buildings in which the occupant load varies widely and more or less unpredictably. Typical buildings in which carbon dioxide controlled systems have proved beneficial include auditoriums and other large public premises. 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 loads. Inexpensive presence sensors can also be used to control the ventilation rates in such cases.

This paper discusses the performance of demand-controlled ventilation systems installed in an auditorium, a conference room, and a school. Both the auditorium and the conference room were originally equipped with a temperature-controlled variable-air-volume (VAV) system. The control systems were later supplemented with carbon dioxide sensors for monitoring the air quality. The ventilation system for the school was modified from a mechanical exhaust air system to a supply and exhaust system with heat recovery. Presence sensors of the infrared type are used to control ventilation rates in the classrooms.

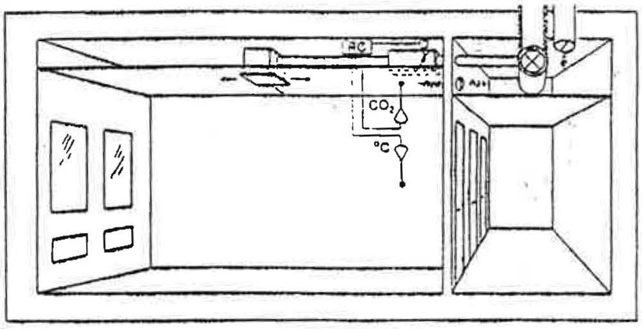

Figure 1 Design of a VAV system with combined air quality and temperature control

SYSTEM DESIGNS

Demand-controlled ventilation systems installed earlier in various types of buildings were usually based on a constant-air-volume (CAV) arrangement with a variable proportion of recirculated air. However, air recirculation is relatively unusual today in newly installed ventilation systems. When a VAV system is employed, the outdoor airflow rate can be varied without having to recirculate air.

The airflow in a VAV system is usually adapted to satisfy heating and cooling requirements. VAV systems, however, can also control air quality. Figure 1 shows the design of a VAV system in which air quality is supervised by means of a carbon dioxide sensor. In this system, both the carbon dioxide and temperature sensors are connected to the control unit normally supplied with a VAV system.

The sensors used to date for ventilation based on air quality control are mainly carbon dioxide sensors and sensors that react to air quality in a more unspecified manner. Carbon dioxide sensors usually function according to the principle of infrared light absorption (nondispersive infrared method). A new type of sensor for carbon dioxide, operating on the photoacoustic principle, is also available now. This type of sensor is utilized for control of the airflow both in the auditorium and in the conference room.

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A simple ventilation system had to be chosen for the school. A presence sensor is utilized for control of the airflow to the classrooms, i.e., the airflows are reduced to a basic flow when the rooms are not occupied and increased to full flow when the rooms are occupied. The presence sensor used is of the passive infrared type.

INSTALLATIONS

The long-term performance of the demand-controlled ventilation systems described here has been studied for 3 years in the auditorium and for about 1.5 years in the conference room and school. A comprehensive measurement program has been going on with the aim of establishing the quality of the air under different operating conditions and to determine the opportunities available for saving energy. Special attention has also been paid to the reliability of the control systems and to the stability of the sensors. The investigations in the conference room and in the school have been supported by the Swedish Council for Building Research.

Auditorium Installation

The newly built auditorium studied was completed during the spring of 1988 (Strindehag and Persson 1990). It has a volume of 390 m^3 and is designed to accommodate 60 persons. The VAV system can deliver supply air to the premises at any rate between 210 and 500 L/s, with the exception of a basic flow of 50 L/s that does not pass through the flow controller.

The carbon dioxide sensor is located midway along one of the auditorium's side walls, about 3 m above the floor. The temperature, airflow, and carbon dioxide content are indicated continuously on a display unit in the room. The airflow is measured with the sensor normally supplied with the VAV system.

The control unit is preset so the output signal from the carbon dioxide sensor begins to control the airflow when the carbon dioxide content of the room air rises above 600 ppm. If good air quality is to be maintained in an auditorium, it is desirable to restrict the carbon dioxide content to 800 to 900 ppm.

Measurements of the carbon dioxide content, airflow, and room temperature were taken in the auditorium under different occupant loads and outdoor conditions. For example, Figure 2 shows that the airflow can be adjusted very quickly to the prevailing occupant load when a combination of temperature and carbon dioxide control is employed. The carbon dioxide content was measured when 51 persons were present in the auditorium for two hours. During this time, the carbon dioxide content did not exceed 800 ppm, which was due to the fact that the airflow through the flow controller increased quickly from the original value of 210 L/s to about 500 L/s when the carbon dioxide level exceeded 600 ppm.

The measurements presented in Figure 2 were made in February 1991, three years after the demand-controlled ventilation system went into operation. The results agree very well with the results obtained in 1988 during the first tests of the system (Strindehag and Persson 1990). These measurements indicate that the control system is very stable; however, it is recommended that carbon dioxide sensors of the type in question should be recalibrated every second year. The airflow sensor utilized for measuring the supply airflow does not seem to need recalibration even after three years of operation.

Conference Room Installation

The conference room has a floor area of 33 m^2 and a volume of 90 m^3 and is served by a VAV system. A carbon di-

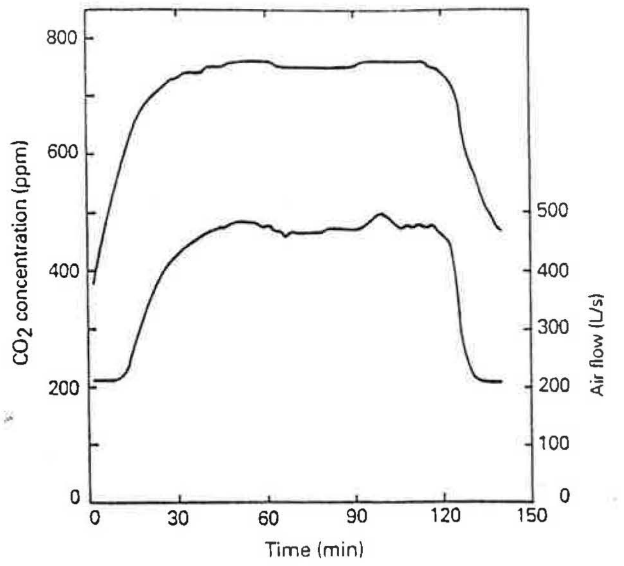

Figure 2 Measured carbon dioxide content and airflow in an auditorium when the ventilation system is under combined temperature and carbon dioxide control and 51 people occupy the premesis

oxide sensor is located in the vicinity of one of the exhaust air devices in the conference room. The control system is adjusted in such a manner that the output signal from the carbon dioxide sensor begins to control the airflow when the carbon dioxide content has exceeded 600 ppm. The measured values of room temperature, carbon dioxide content, and supply airflow are shown in Figure 3 for a working day during which the occupant load in the conference room varied widely.

As shown in Figure 3, the rate of airflow 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 800 ppm, which is about 450

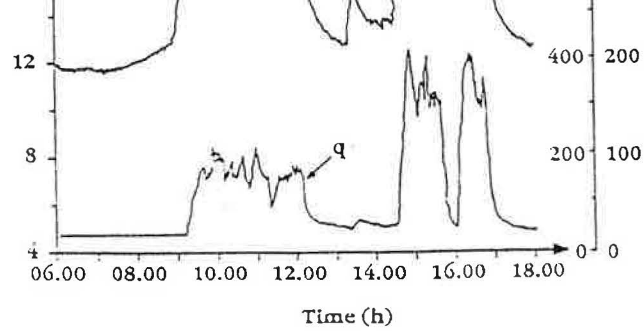

Figure 3 Measured values of room temperature (t), carbon dioxide content (c), and supply airflow (q) in a conference room ventilated by a VAV system with temperature and carbon dioxide control

ppm higher than the content in outdoor air. At maximum occupant load in the room, the supply airflow is about 210 L/s. However, the mean value of the supply airflow during the 11.5 hours of operation of the ventilation system was only 60 L/s.

If a constant-air-volume (CAV) system had been selected instead of a VAV system for ventilating the conference room, it probably would have been rated for a supply airflow of 10 L/s per person, 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 content at the highest occupant load would have been higher, since the supply airflow to the room would have been restricted to 150 L/s, which is only 71% of the flow supplied by the VAV system.

The measurements in the conference room show, in accordance with previous measurements in another conference room (Norell and Strindehag 1988), that the amount of carbon dioxide generated is proportional to the occupancy level in the room. It is assumed that an adult person typically produces 15 to 20 L/h of CO_2 at an activity level of 1.2 met units (ASHRAE 1989).

School Installation

During 1989 a system for demand-controlled ventilation was installed in a school building with six classrooms. The building was originally ventilated by a mechanical exhaust system, which gave relatively low airflows, i.e., only about 2 L/s per pupil. This system was replaced by a mechanical supply and exhaust system with heat recovery. The ventilation rate in the various classrooms is now controlled by a presence sensor, which means that the supply airflow is increased from a basic flow of 28 L/s to 225 L/s when the room is occupied. This flow corresponds to 9 L/s per pupil if 25 pupils are present. The pressure in the supply air system is kept constant, independent of the airflow, by the guide vane control of the fan. The control of the exhaust air is coupled to the control of the supply airflow (see Figure 4).

Since the installation of the new ventilation system, the carbon dioxide content and the airflow to the classrooms have been measured several times. Usually, the limit value of 1,000 ppm is not exceeded, and an average value of about 800 ppm is typical during lessons. Before the installation, the carbon dioxide content could be kept below 2,000 ppm only by opening the windows during the breaks.

An airflow of 8 to 9 L/s per pupil seems to provide acceptable air quality according to the experience at this school. Moreover, the demand-controlled ventilation system with presence sensors has turned out to operate very reliably. The energy saving also seems to agree with the calculations. However, installation of a more efficient heat recovery system would probably have resulted in the same energy saving at a lower cost.

CONCLUSIONS

The measurement programs in the auditorium and the conference room have demonstrated that demand-controlled ventilation based on carbon dioxide control can provide major benefits in buildings in which the occupant load varies unpredictably.

The reliability of the systems also seems to be good according to the long-term tests, which extended up to 3 years in the auditorium and up to 1.5 years in the conference room.

In schools, simple demand-controlled ventilation systems should preferably be installed, utilizing presence sensors and on-off control of the airflow to the classrooms.

REFERENCES

ASHRAE. 1989. *ASHRAE Standard 62-1989, Ventilation for acceptable indoor air quality*. Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

Norell, L., and O. Strindehag. 1988. "VAV systems with air quality control." *VVS & Energi*, October, pp. 82-86 (in Swedish).

Strindehag, O., and P.G. Persson. 1990. "Demand-controlled ventilation." *Building Services*, February, pp. 55-56.

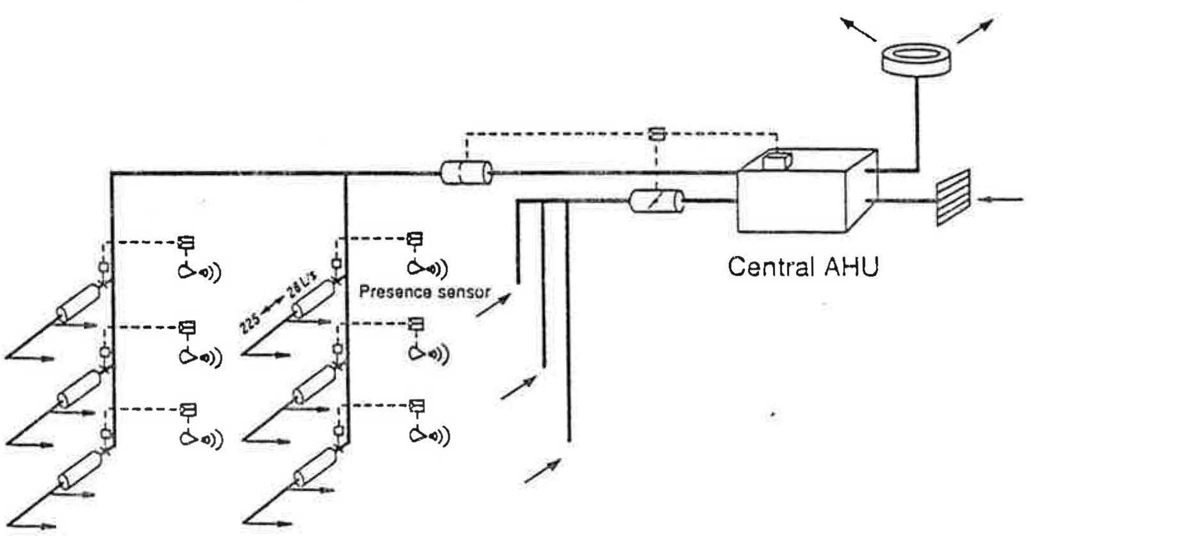

Figure 4 Diagram of the ventilation system for a school with six classrooms (normal flow, 225 L/s; basic flow, 28 L/s)