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Demand-controlled ventilation

An auditorium at Fläkt Evaporator AB, Sweden, shows the benefits of controlling ventilation systems through carbon dioxide measurement. *Ove Strindehag* and *Per-Göran Persson* report.

In many buildings the benefits of maintaining good air quality are offset by unnecessary consumption of energy for heating, cooling and distribution of the ventilation air.

Good air quality can be maintained at minimum energy consumption by controlling the ventilation rate to suit the contaminant content in the indoor air. In buildings with this type of demand-controlled ventilation, it is generally assumed that the occupants are the principal contaminant source. Therefore, in such cases, the air quality can be monitored by carbon dioxide sensors.

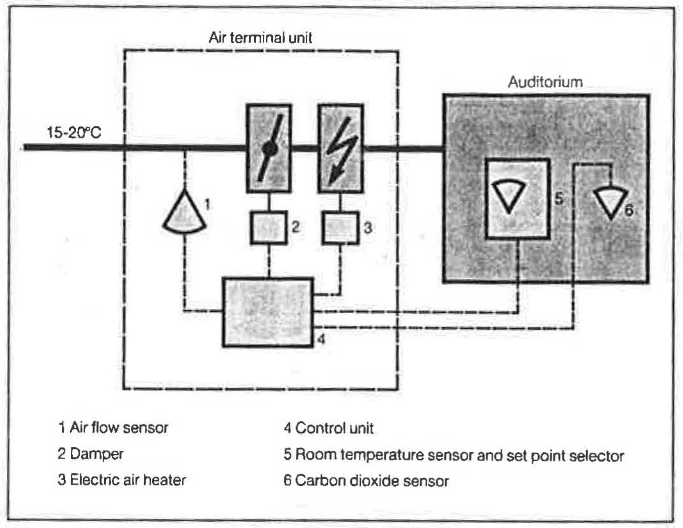
An adult person produces, typically, 15-20 litres of CO_2/h as part of their normal breathing process. For a given activity level it is safe to assume that the amount of CO_2 generated is proportional to the occupancy level in the building. Hence by employing a CO_2 sensor in the ventilation control system, airflows can be set to suit the occupancy level.

A newly-built auditorium at Fläkt Evaporator AB in Jököping, Sweden, utilises such a demand-controlled ventilation system. The auditorium is designed for a maximum occupancy level of 60 people. The floor area is 100 m^2 and the ceiling height 3·9 m, hence the volume of 390 m^3 corresponds to 6·5 m^3/person at full capacity.

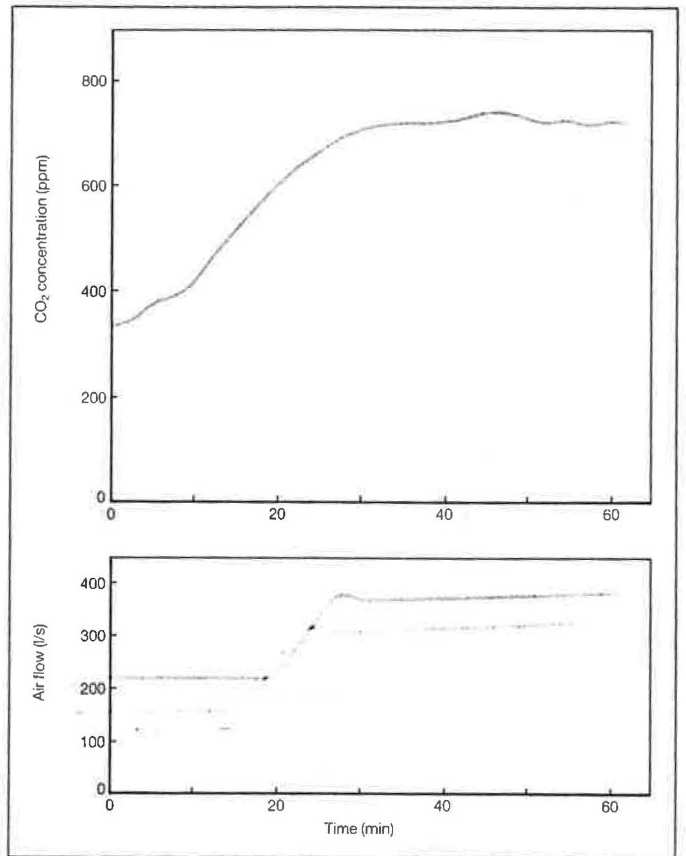
The auditorium is equipped with a vav ventilation system. In such systems, the air flow is normally varied to maintain the required temperature in the premises. However, a vav system can very well operate as a demand-controlled system, the air is then controlled to maintain a certain air quality.

Air is supplied to the premises at floor level by Fläkt low velocity supply devices. The exhaust air is vitiated through two long slot type devices located in the ceiling adjacent to each long wall. The ventilation system cools the premises and lphw radiators are used to supply make-up heat at low outdoor temperatures.

The system can deliver supply air at any rate between 220 and 500 litres/s. In addition, the system supplies a basic flow rate of 50 litres/s which does not pass through the flow controller in the supply air terminal unit.



Above, figure 1: Diagrammatic arrangement of the control system for the auditorium.



Above, figure 2: Measured CO_2 concentration and air flow when the ventilation system is under combined temperature and CO_2 control and the auditorium is occupied by 30 persons.

Supply air is cooled or heated in a central ahu to a temperature of 15–20°C, depending on the outdoor temperature. The ahu is also equipped with a humidifier.

The supply air flow rate is measured in the terminal unit by means of an orifice plate and a differential pressure sensor connected to it. The flow controller increases the air flow on a rise in room temperature or an increase in the CO_2 content. The air flow supplied to the room is not affected by pressure variations in the duct system of the building.

The CO_2 sensor and the temperature sensor are both connected to the control unit normally included in the vav system (see figure 1). The sensor that controls the outdoor air flow at any given time is dependent on factors such as the occupant loading, outdoor temperature and solar loading.

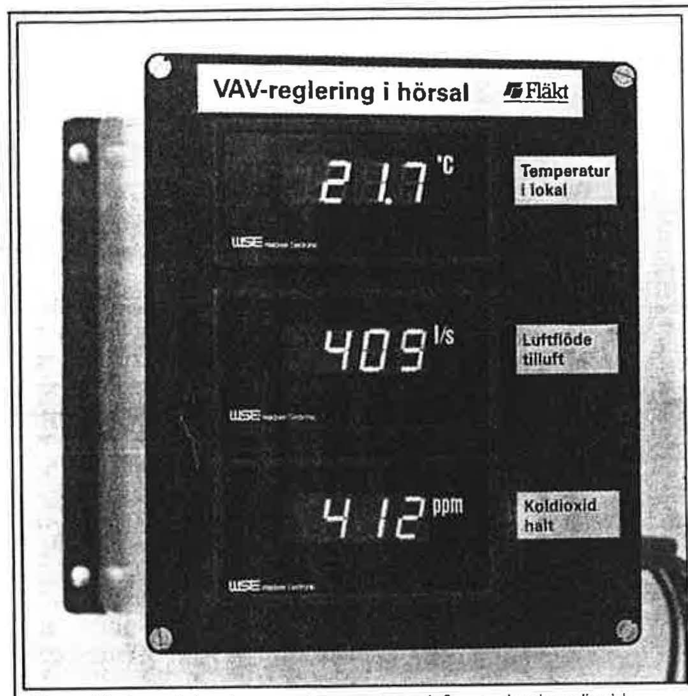
The CO_2 sensor, which operates on the photo-acoustic principle, is well suited for measuring the CO_2 contents occurring in indoor air – those generally ranging between 300 and 2000 ppm. Moreover, the low price of the sensor makes it justifiable for demand control and monitoring.

The control unit is preset so that the output signal from the CO_2 sensor begins to control the air flow when the CO_2 content of the room has risen to more than 600 ppm. If good air quality is to be maintained it is desirable, in an auditorium, to restrict the content to 700–900 ppm. Higher CO_2 content may affect the attentiveness of the auditorium occupants.

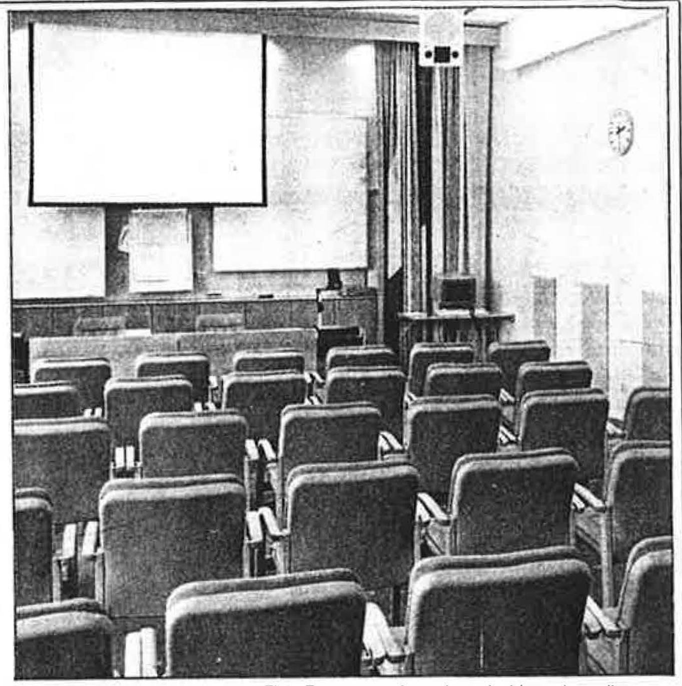
The air quality in the auditorium is monitored by the CO_2 sensor, which is located midway along one of the long walls, about 3 m above the floor. The CO_2 content, along with the indoor temperature and supply air flow rate, is indicated on a display unit at the rear of the auditorium.

Numerous readings of CO_2 content, air flow and room temperature were taken in the auditorium at different occupant loadings and different outdoor conditions. The measured CO_2 contents agree very well with the expectations, based on the assumption that an adult person doing sedentary work emits 15–20 litres of CO_2/h. One can conclude that measurement of CO_2 content in a room provides a quick check of whether or not the correct rate of outdoor air flow is being supplied to the room.

Figure 2 shows an example of the readings taken in the auditorium, which had previously been empty for several hours. The CO_2 content and the



Above: Display unit showing room temperature, air flow and carbon dioxide content.



Above: The new auditorium at Fläkt Evaporator is equipped with an air quality controlled vav system.

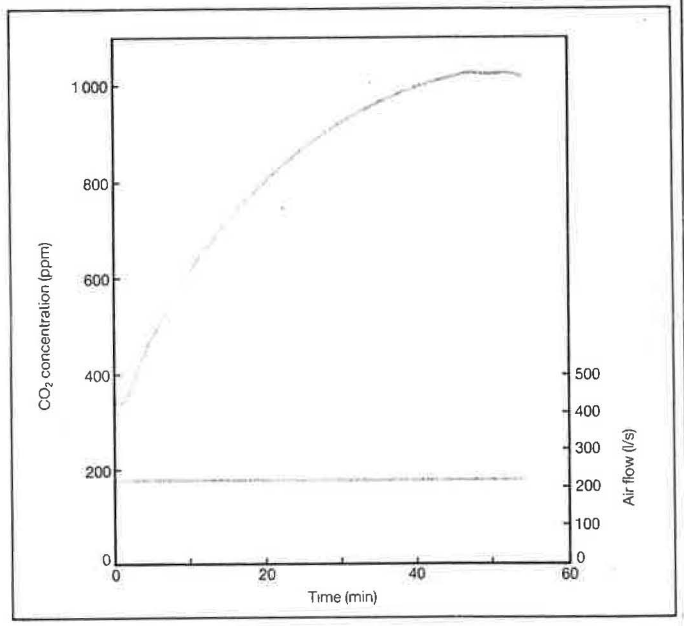
air flow changes for the hour following entry of 30 people is shown.

When measurements were started, the CO_2 content in the room air was around 340 ppm, which agrees very closely with that of outdoor air. The air flow was initially 220 litres/s, but increased quickly to about 380 litres/s when the CO_2 level rose to more than 600 ppm. Due to the increased air flow, the CO_2 content was restricted to a maximum of 750 ppm.

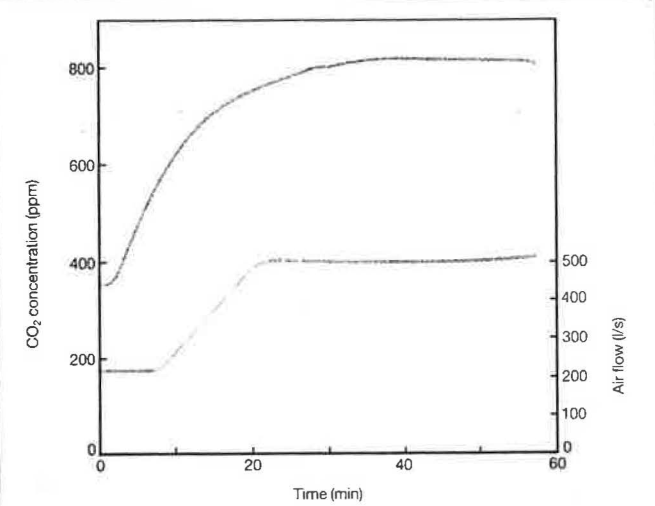
Figures 3 and 4 illustrate that a vav system in which both temperature and CO_2 control are combined can adjust the air flow very quickly to suit the prevailing occupant loading.

In the first case, 44 people were present in the auditorium for almost one hour and the vav system was only temperature controlled. The CO_2 content increased to about 1020 ppm in 50 minutes. During this period the air flow did not have time to change and remained at the original value of 220 litres/s. On this occasion the room thermostat setting was 22°C.

Figure 4 illustrates the sequence of events in the normal case when the vav system is under both temperature and CO_2 control. The room thermostat setting was also 22°C. Although the number of occupants was somewhat higher – 51 persons as compared to 44 in the previous case – the CO_2 level did not exceed 820 ppm.



Above, figure 3: Measured CO_2 concentration and air flow when only temperature control is operative and the auditorium is occupied by 44 persons.



Above, figure 4: Measured CO_2 concentration and air flow when the ventilation system is under combined temperature and CO_2 control and 51 people occupy the auditorium.

This is because the air flow increased quickly from the original value of 220 litres/s to about 500 litres/s when the CO_2 content exceeded 600 ppm. As illustrated by the measurements carried out, it is advisable to combine temperature and CO_2 control to meet all of the loading conditions that may occur in an auditorium.

The measurement programme has demonstrated that demand-controlled ventilation can provide major benefits in premises in which the occupant loading varies unpredictably and also in which the activities demand a good indoor climate with good air quality.

In addition to auditoria, these conditions also apply to schools and other educational premises in which strict demands are made on the concentration performance of the occupants, ie faculties that are highly dependent on the room temperature and air quality.

The Swedish Council for Building Research is providing support for the planned installation of air quality controlled vav systems in schools and similar premises.

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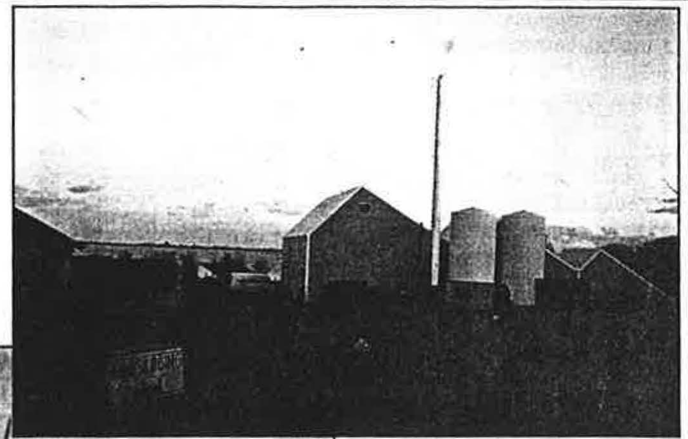
Aero energy co-operative

J Schultz and *K Beattie* report on a combined heat and power plant in Aeroskoebing, Denmark, which meets 90% of the town's heating requirements while making maximum use of indigenous fuel.



Above: The renewable energy plant at Aeroskoebing.

Above: The two 200 kW windmills produce 783 MWh annually.

In 1981 a group of citizens on the Danish island of Aero became interested in the construction of a renewable energy plant for the island's largest town, Aeroskoebing. The aims of the group were to use indigenous fuel on the island for energy and reduce the dependence on imported fuel oil. The island has a population of 9000 and an area of 88 km^2.

The Aero energy co-operative is now operating the new chp plant which is providing 90% of the town's district heating requirements as well as a considerable part of the electrical power consumption.

The co-operative consists of representatives from the county council, farmers, power plant company, district heating company and originators.

In the fight against pollution the plant replaces the use of fuel oil and so spares the environment the effects of sulphur from the fuel oil. Highly efficient burning in the straw boiler combined with effective flue gas purification eliminates the pollution involved in burning straw in the fields, as well as using a fuel which would otherwise be wasted.

The combined energy plant consists of a 1600 kW straw burning boiler, a 325 kW electrically driven heat pump, a 140 kW diesel motor generator, two 200 kW windmills, 1000 m^2 of solar panels and heat accumulation tanks of 235 m^3.

The straw burning unit is the largest heat-producing part of the system and produces approximately 60% of the plant's total heat output. The 225 m^2 barn can house 120 straw bales, each weighing ½ tonne, which covers up to five days consumption in the winter period. The annual straw consumption of around 2500 tonnes is stored in a number of nearby barns. This accounts for approximately half the surplus straw which exists from Aero's farming.

After delivery to the plant, the large bales are transported automatically by crane up to a closed straw divider, after which the loose straw is fed by a stamp into the unit. The straw contains 3-7% ash which is returned to the fields as wet ash.

The heat sources for the heat pump are the 1000 m^2 of solar panels; the straw boiler flue-gas condenser; the diesel generator flue-gas condenser and the engine room space cooler.

The solar panels are divided so that half are situated on the south facing roofs and half on stands in the surrounding grounds facing 20° south-west. The solar panels are made of black plastic and are not covered by glass since the higher temperatures associated with glass covered panels are of no particular advantage to the heat pump circuit. The panels are capable of absorbing heat from the air until the ambient temperature is as low as 5°C. However, the absorber water containing 10% of glycol as antifreeze protection will not achieve temperatures higher than 30°C (see table 1).

The straw boiler flue-gas condenser and diesel motor condenser reduce the flue gases to below the condensing temperatures so that as much heat as possible can be recovered. The space cooler recovers radiant and convective heat from the diesel generator plant and heat pump.

Heat is also recovered from the diesel motor generator using a a heat exchanger on the motor cooling water circuit. The electricity produced by the generator is partly used to operate the heat pump and ancillary plant, and partly sold to the electricity company.

Table 1: Solar panel performance

Month (1989)	Solar energy available (kWh)	Heat produced from solar energy (kWh)	Panel efficiency (%)	Average water temperature entering solar panels (°C)	Average water temperature leaving solar panels (°C)
Feb	2877	0	–	4·99	19·08
Mar	32 366	8530	26	7·25	20·33
Apr	92 352	4600	5	10·00	15·52
May	150 622	45 470	30	17·05	21·97
Jun	139 633	83 770	60	20·28	21·02
Jul	124 920	92 050	74	19·16	19·90