FIELD MEASUREMENTS OF AIR QUALITY CONTROLLED VENTILATION

Ulla Suomi
Research Engineer
EKONO Consulting Engineers
Finland

Olli Seppänen
professor
Helsinki University of Technology
Finland

ABSTRACT

The present paper reviews some results of the project "The requirement adapted ventilation system" which is a part of an extensive research project "Indoor Air Quality and Ventilation Requirements" which was started in Finland in 1983.

According to the field measurements CO_2 seems to be the most reliable indicator for the air quality in spaces where smoking is not allowed. The variation of particles and quantity of combustible gases depend on smoking but not on the occupancy load.

P-, PI- or PID-controllers can be used in air quality controlled ventilation system if the rate of change in the air quality indicator is slow and devitation between set point and measured value is accepted. The best result can usually be accomplished with a PID-controller. Because of the long integration time needed in a controller for example in CO_2-controlled ventilation a standard controller is not suitable but a digital controller is needed. If the rate of change in air quality indicator is rapid a PID-controller is needed to avoid undesirable fluctuations in the control loop.

1. INTRODUCTION

Large savings can be achieved without reducing the indoor air quality if the outdoor air intake can be controlled by demand. To accomplish these savings an indoor air quality monitoring indicator is required. It has to measure the occupancy load or indoor air pollutants such as tobacco smoke and impurities from the building materials.

This paper deals with the results from the field measurements in which the relationship between CO_2, particles and combustible gases in various buildings were measured and analyzed. Results from the tests with an air quality controlled ventilation system in one building are presented, too.

2. MEASUREMENT OF THE INDOOR AIR QUALITY

2.1 Methods

Variation of CO_2-concentration, particle concentration and quantity of combustible gases in the indoor air was measured and recorded in thirteen buildings for approximately one week of each. Samples were taken from either room or exhaust air. The latter location was used in buildings like department store, theatre, dining hall and offices. In one building ventilation was also controlled depending on CO_2-concentration or quantity of combustible gases. The CO_2-concentration was monitored with a nondispersive infrared gas analyzer. The variation of particle concentration was monitored with a modified electrical aerosol monitor (1). Variation of combustible and reducing gases (e.g. CO, SO_2, Ammonium, Bentzene etc.) was measured with an "air quality sensor" by Stäfa which is based on semiconductor technique.

2.2 Main Results of the Field Measurements

The measurements and analyses indicated that CO_2-level is an accurate and reliable indicator of air quality in regard to the occupancy load in a given space. However, when smoking is allowed, the CO_2-level alone is not as reliable as cigarrette smoke does not appriciately affect the CO_2-level.

The other two measured indicators (variation of particles and quantity of combustible gases) proved to be more reliable in spaces where smoking is allowed as both of these indicators react to tobacco smoke. However, since neither of these latter indicators react reliably to occupancy load, neither nor both can be well used as the only means to control air quality and ventilation.

In some offices measurements were taken from both inside the room and from exhaust air. According to these measurements it was found that a PID-controller is necessary for satisfactory control when measurements are made from room air and smoking is allowed. Figure 1 shows the variation of particle concentration and combustible gases in an office room where smoking is allowed.

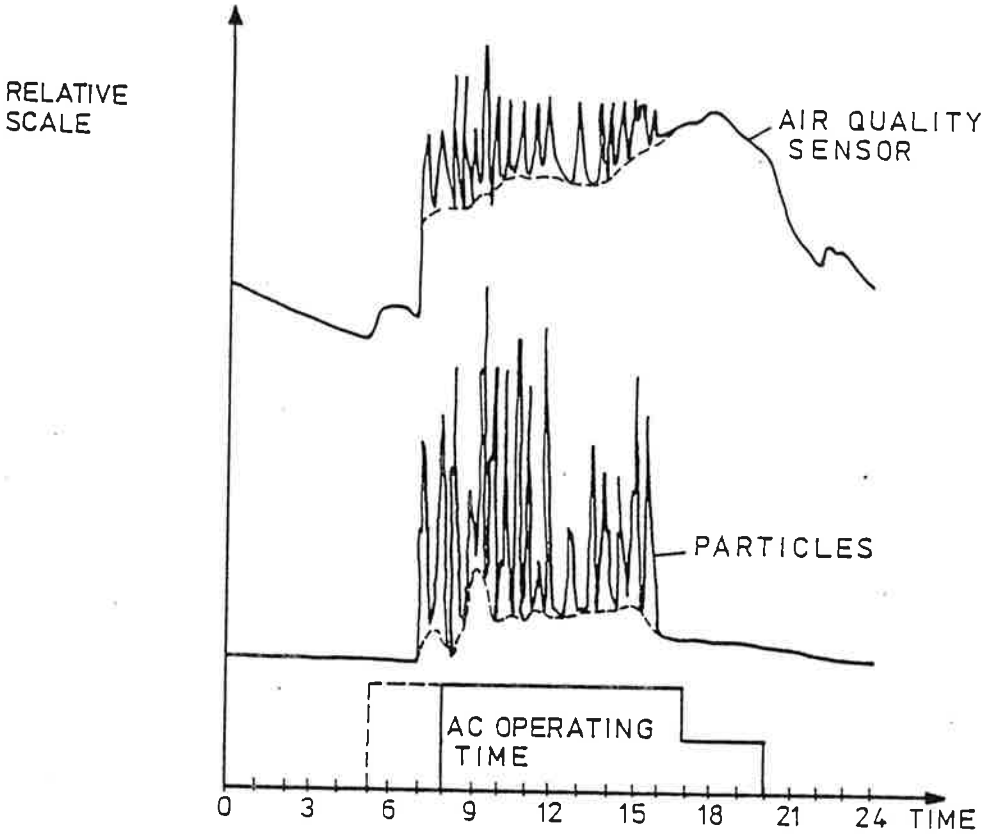

Figure 1. The variation of the particle concentration and of combustible and reducing gases (air quality sensor) in an office room where smoking is allowed.

As seen in figure 1 tobacco smoke tends to alter the air quality (according to these indicators) so swiftly and dramatically that it is rather difficult to find an adequate air quality control system and parameters of the controller even if we have a PID-controller.

3. AIR QUALITY CONTROLLED VENTILATION IN ONE OFFICE BUILDING

3.1 Ventilation Control System

In one office building outdoor airflow was controlled according to the CO_2-level and the variation of combustible gases (air quality sensor). The ventilation control was carried out like shown in figure 2.

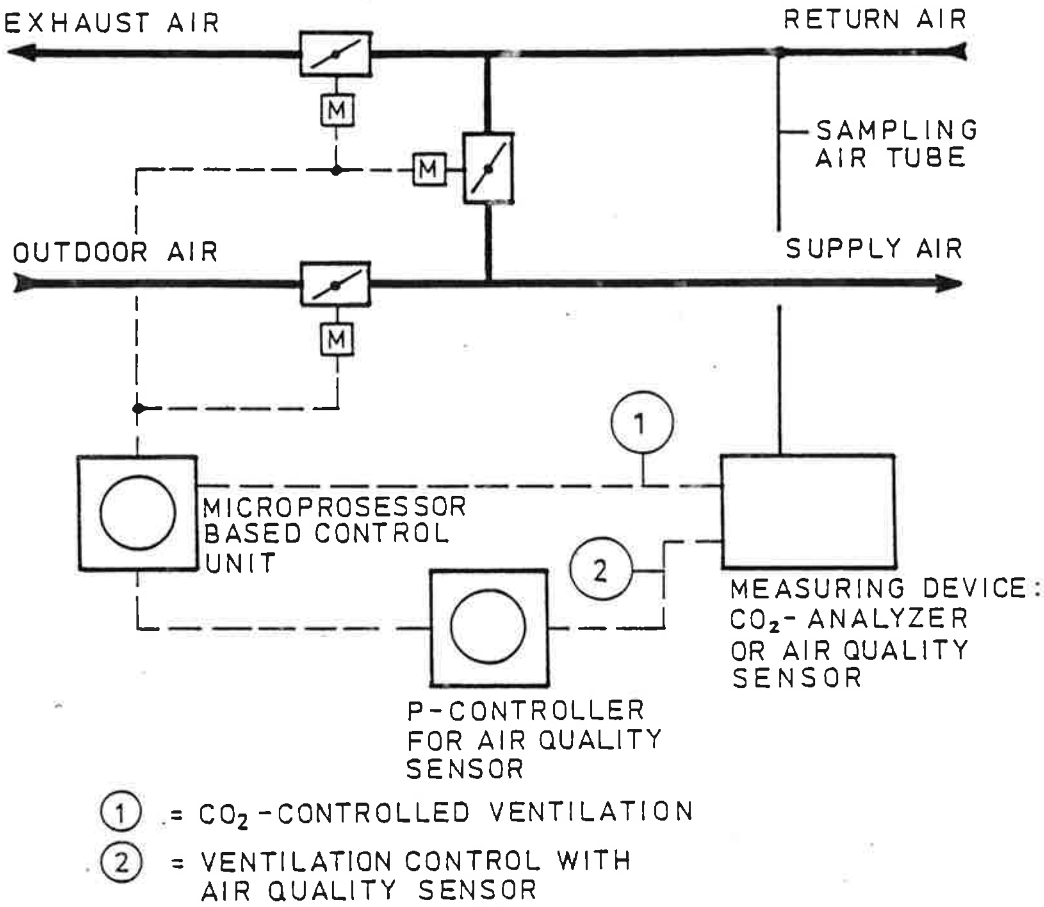

Figure 2. Controlling of the outdoor air flow in test building.

The air was pumped to the measuring device from the return air duct after the fan. The microprosessor based control unit in the building regulated the motor dampers. The set point for CO_2-level was in these tests 650 ppm. In the other test, when the air quality sensor was used, the opening of outdoor air damper depended on output voltage of the sensor. The calibration of the sensor was done separately.

The controller for air quality sensor was a P-controller but in CO_2-controlled ventilation system algorithms were programmed in the microprocessor based control unit.

3.2 CO_2-controlled ventilation

In these tests the variation of CO_2-concentration and the opening of the outdoor air damper were monitored with PI- and PID-controller.

Minimum outdoor air damper position was set to 20 %. This outdoor air flow will take care of the pollutants from building materials. The rest of outdoor air intake is controlled according to the occupancy load (CO_2-level). The set point used for CO_2-level was 650 ppm.

Figure 3 represents the variations of CO_2 concentration when PI-controller was used. Parameters of the controller were K_p = 1,0 (corresponding proportional band of 100 ppm of CO_2) and K_I = 30 min based on the previous studies (3).

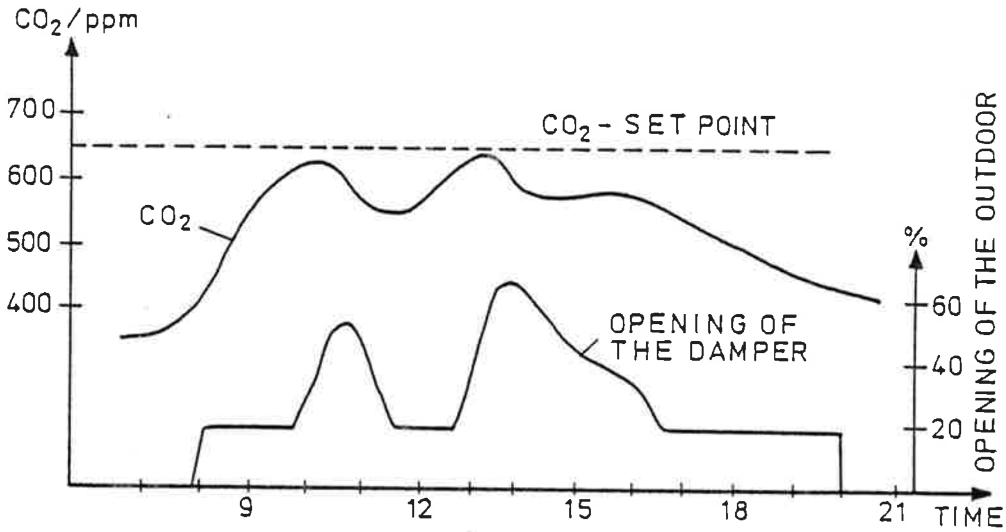

Figure 3. Outdoor air flow control according to the CO_2-concentration when PI-controller was used.

Slow changes in CO_2-concentration indicate rather long time constant of the system. So the integration term was set to 30 minutes. The integration time for a standard controller is only 1-10 minutes and so a digital controller is required if undesirable fluctuations in the outdoor air flow should be avoided.

In this case the outdoor air damper started to open over the minimum position (20 %) when CO_2-concentration was about 610 ppm. With this PI-controller CO_2-concentration was whole day under the set point (650 ppm). Also the lunch time can be seen clearly in the reduction of CO_2-concentration.

Figure 4 represents a day when PID-controller was used. The parameters of the controller were K_p = 1,0, K_I = 30 min and K_D = 0,5. Set point for CO_2-concentration was again 650 ppm and the minimum outdoor air damper opening 20 %.

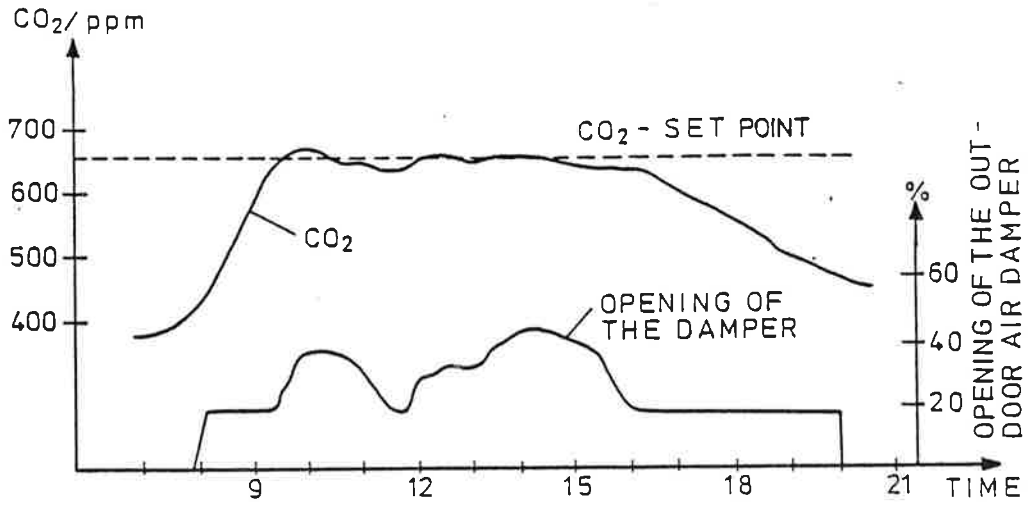

Figure 4. Outdoor air flow control according to the CO_2-concentration when PID-controller was used.

As seen in figure 4 CO_2-concentration in return air duct holds the set point well. Maximum opening of the outdoor air damper during the day was 45 %.

In both cases control loop was stable and no undesirable fluctuation was seen. At least in this case the PID-controlled system gave better result and also more energy is saved compared to the PI-controlled system.

CO_2-controlled ventilation with P-controller was not tested, but with such controller there will always be deviation between the set poin and the actual CO_2-concentration. If the deviation from the set value is accepted the controller for CO_2-controlled ventilation system can be P-, PI- or PID-controller although the best result can be accomplished with a PID-controller.

3.3 Ventilation Control with an Air Quality Sensor

Ventilation was also controlled with a P-controller which was connected to the air quality sensor. For this measuring device the P-controller is the only available alternative.

In this test the difficulty was to find the right set point to the air quality sensor. In addition the variation of the output of the sensor was very small during the day in this building (fig. 5) which requires a narrow proportional band. The output of the sensor changed from day to day so much that reliable control result was impossible to accomplish and outdoor air flow rate changed drasticly. This caused that outdoor air flow varied noticeably during different days.

The opening of outdoor air damper was completely different from what was obtained from CO_2-control. No explanation was found for the changes in the output of air quality sensor.

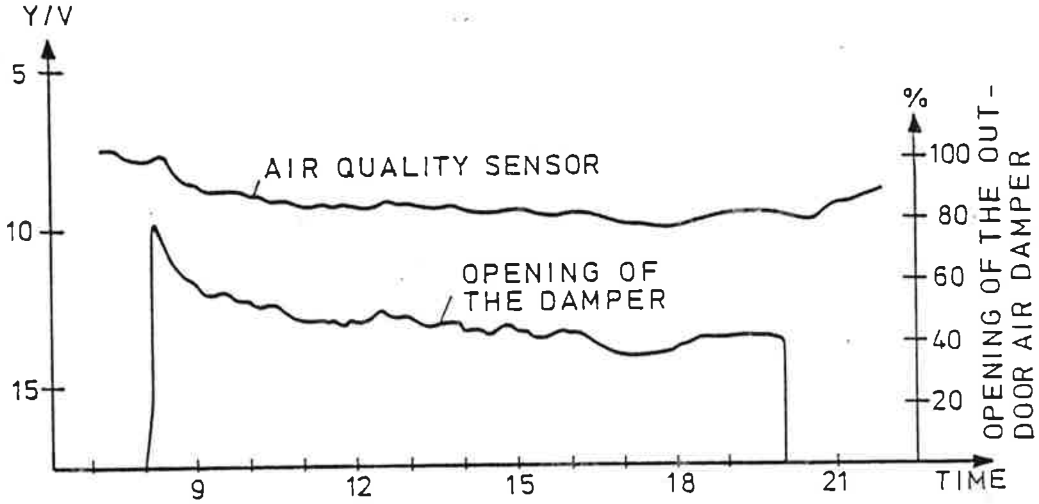

Figure 5. Outdoor air flow control according to the output (Y) of the air quality sensor.

With P-controller the opening of the outdoor air damper followed all changes in the variation of the air quality sensor. When air sample is taken from return air duct the control loop is stable because the output of the air quality sensor varies quite slowly in return air. The situation is completely different if the sample is taken from a room where smoking is allowed. In such case P-controller causes easily instability in the control loop.

4. CONCLUSION

At the present time, CO_2 seems to be the most reliable indicator for the air quality, especially in spaces where smoking is not allowed. It is, however, likely that in the future the measuring devices based on semiconductor technique will become more reliable and devices which measure particles in the air will become more inexpensive.

In respect of control stability any of the control algorithms (P, PI, PID) can be used with CO_2 and also with other indicators of air quality if the air sample is taken from return air duct, however PID controller gives the best result. If variations in the air quality are slow (like CO_2-concentration) the integration time in controller should be rather long.

If the indicator for the air quality is particles or combustible gases or some other indicator which have quick variations a PID-controller is needed to avoid undesirable fluctuation in control loop.

Although the possibilities for economic air quality controlled ventilation system are already available in many buildings, inexpensive and more reliable sensors and controllers need to be developed before such control system becomes generally used.

References

1 LEHTIMÄKI, M., "Modified electrical aerosol detector", Aerosols in the Mining and Industrial Work Environments, Vol. 3. (Marple, V.A. & Lin, B.Y.H., eds.) Ann Arbor, Michigan 1983, pp. 1135-1144.

2 KUUSELA, L., PEKKONEN, J., SUOMI, U., The requirement adapted ventilation system, EKONO Oy, Indoor Air Quality and Ventilation Requirements, Helsinki University of Technology Report C:9, Espoo 1984.

3 SÖDERGREN, D., PUNTTILA, A., A CO_2-controlled ventilation system, Pilot study, Swedish Council for Building Research, D7:1983.