CONTROLLING OF THE OUTDOOR AIR INTAKE BY THE USE OF CONTAMINANT MONITORING

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Introduction

Large monetary and energy savings can be achieved without reducing the indoor air quality if the outdoor air intake can be controlled according to need. The control requirement to accomplish these savings is a suitable indoor air quality monitoring indicator which measures the occupancy load and other indoor air pollutants such as tobacco smoke and impurities from the building materials.

This paper discusses the results of a field measurement study in which the relationship between CO_2, particles and combustible gases in different types of buildings were measured and analyzed. The technical feasibility of this system being used commercially with various HVAC techniques and the health risks and economics of such a commercial system are also discussed.

Monitoring of the Indoor Air Quality

Study Technique

Variation in CO_2-concentration, particle concentration and quantity of combustible gases in the air were monitored and recorded in thirteen buildings for approximately one week in each location. Measurements were taken from either room air or exhaust air in such diverse building types as a department store, a theatre, a dining hall and several offices. 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, Ammonia, Bentzene, etc.) was measured with an "air quality sensor" which is based on a semiconductor technique.

Results of the Field Measurements

The measurements and analyses indicated that the 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 appreciably 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.

Correlation between the three measured indicators varied in the different locations. The best correlation was found in the department store where all three indicators correlated well during the measuring period. In the dining hall, on the other hand, the CO_2-measurements had no correlation with the measurements of the other two indicators. The reason for this was probably the result of vapours from the adjacent kitchen entering the dining hall. In the theatre, only CO_2 seemed to be a reliable indicator of the occupancy level although the particle measurements and air quality sensor readings sometimes also recorded a correlation with the CO_2-measurements.

In offices, the measurements were taken from both inside the room and from exhaust air. The results appear to be inconsistant. During some days, all three sensing devices were in excellent correlation, however, on other days, in the same location, no correlation could be found between any of the indicators. Because tobacco smoke tends to alter the air quality so swiftly and so dramatically, measurements from room air tended to react too rapidly, to affect an adequate air quality control system. We found that a PID controller is necessary for satisfactory control in these smoking areas. In exhaust air all measured indicators varied in general so that a P-controller could suffice as the only control element.

Different Air Conditioning Systems

Study results indicate that the variation of the CO_2, particles and air quality sensor readings is independent of the type of air conditioning system used. Analyses also indicate that almost all air conditioning systems can be adapted to control outdoor air intake by the requirements of the air quality. Such an air quality controlled ventilation system is easiest to apply when altering the recirculation air volume is possible, and the air quality needs to be measured at one point only. If the air conditioning system does not include recirculation, but uses only outdoor air, the application is slightly more complicated because variation in air flow has an effect on the throw of supply air from the terminals. Buildings with induction unit systems are the most difficult to control by this air quality demand technique.

Effects on Indoor Air Quality and Eventual Risks

When the air conditioning system is controlled with one indicator (e.g. CO_2, which is a reliable indicator in regard to occupancy load), it must be known that there are no other impurities (e.g. from building materials) which would demand more fresh air than that required by the occupancy load.

This can normally be accomplished by establishing a minimum ventilation rate, such as 0,5 exchanges per hour, which will take into account the impurities from building materials, and then controlling the additional outdoor air intake according to the occupancy load.

In buildings where smoking is allowed, the outdoor air requirement is usually larger than for other buildings. In such buildings, the recommended technique is to measure two indicators (e.g. CO_2 for occupancy levels and CO for quantity of smoke in the air), and then control the ventilation system according to that indicator which calls for the most outdoor air.

To illustrate the effect of smoking to air quality in those buildings where recirculated air is used, we have made computer calculations based on the general mass balance equation. In the following figures, changes in CO-concentration caused by smoking is plotted against varied recirculation rates. Figure 1A uses an air flow of 1,6 l/s, m^2 according to Finnish regulations and figure 1B uses an air flow of 3,5 l/s, m^2 according to typical cooling loads. The calculations assume that approximately 30 % of the occupants smoke approximately 1-2 cigarrettes each hour.

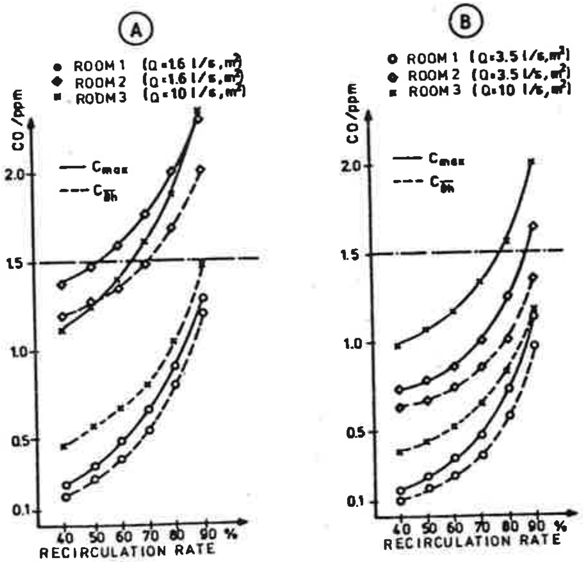

Fig. 1. Changes in CO-concentration in office building caused by smoking. Room 1: non smokers, room 2: smokers, room 3: meeting room.

According to several research findings (2), tobacco smoke causes irritation to healthy people when CO-concentration rises to the level of 1,5 - 2,0 ppm. Figure 1 demonstrates that the CO-concentration does not rise over 1,5 ppm in rooms where only nonsmokers are present even when the recirculation rate is 90 %. In the smokers' room, however, the CO-concentration rises over 1,5 ppm at relatively low recirculation rates (50 %), when the air flow is 1,6 l/s m^2. This illustrates that smoking will probably not cause irritation to occupants of the nonsmoker rooms even though the recirculation may be high, but in rooms where there are both smokers and nonmokers, irritation effects are very probable.

Economy of the System

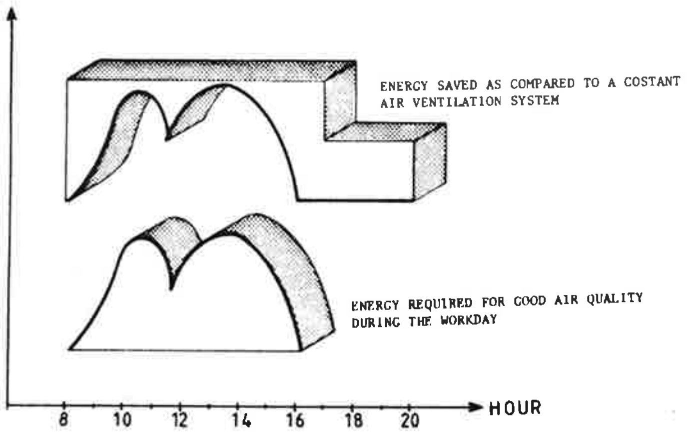

Fig. 2. Energy savings achieved with air quality control ventilation system.

One study in Japan indicates that energy savings of 70 % in air conditioning energy consumption are reliable in department stores with an air quality control system. Usually in different building types, the savings vary between 20 % - 40 %, depending upon the occupancy load in the buildings. The pay back period of such an air quality control system has been calculated to be between 1 and 4 years, depending upon the building's function, the occupancy loads and the type of measuring device(s) used. CO_2-analyzers, for example, are often rather expensive, and therefore prove to be most economical in buildings with high air flows and where the occupancy load varies dramatically during the day.

Conclusion

At the present time, CO_2 seems to be the most reliable indicator for air quality, especially in spaces where smoking is not allowed. In the future, however, it is likely that sophisticated measuring devices, based on the semiconductor technique, will become more reliable and therefore more suitable for controlling air quality, as these can detect such things as human odors and tobacco smoke. Devices which measure particles in the air are at this time intended only for laboratory use and therefore are too expensive for typical building control purposes. Although the possibilities for economic ventilation control by air quality demand are already available in many buildings, sensing devices which are both less expensive and more reliable need to be developed before such control systems become generally used.

Using existing technology and the data obtained by this study, it is appearant that many specific buildings can even now be retrofitted with an air quality control system which, when married to the temperature control system, can provide excellent energy savings and a monetary pay-back of 4 years or less. The key to obtaining these savings, is a thorough engineering study in the existing building which will determine the type of measuring device(s), the balancing system of temperature demand to air quality needs, the optimum locations of the sensing and control devices, and the control strategy which brings about the best combination of health, comfort and energy savings.

References

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