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IAQ-Management by Demand Controlled Ventilation

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Abstract

Research results of the last 2 years clearly showed, that the pollution load in a room originates from a variety of sources. Main sources of concern are emissions from building material, emissions from filters, emissions from dirty ducts, and emissions from occupants according to their activity level. It depends on the building itsself, whether the occupancy load dominates the pollutant level or not.

Demand Controlled Ventilation offers the possibility to control the airflow rate according to the pollution level in a room. The abundance of indoor air pollution gases leads to a classification of control strategies into 3 groups: humidity, carbon dioxide, and volatile organic compounds.

In addition to an effective extraction of the contaminant the detection with a reliable IAQ-sensor is of fundamental interest. This paper focusses on the requirements to IAQ-sensors, compares this with their current performance and highlights new areas of research.

Introduction

Indoor air quality is becoming a bigger and bigger issue in the countries of the European Community. Thightning of the building's envelope and efforts to decrease fresh air intake and energy demands for conditioning the supply air led to the conflict between indoor air quality and energy savings. Enourmous efforts to ensure a good thermal comfort environment in ventilated buildings of today let people (occupants, hygienists, housing authorities, engineers, building managers, etc) now pay more attention to gaseous substances in the air. Due to longer duration of people in indoor air symptoms of poor IAQ like discomfort, irritations, annoyance, and health risks of occupants were placed into the foreground. On the way of solving the sick building syndrom IAQ-analysis is regarded to be one key.

The awareness of material emissions led to a selection of building materials with low source strengths. Deposition of dust in filters and ducts can become another odour source. Furthermore, there are other pollutants in buildings, which generate from people and their activities and from machines (laser printer, copy machines, etc.).

If possible, an extraction at the source is favourable. Many sources move, people walk around, machines were used by several users and displaced from time to time. Where source extraction is not possible, emissions have to be effectively extracted via the ventilation system, either by dilution or by directed airflow (displacement flow).

Excessive ventilation leads, in general, to improved IAQ with the disadvantage of complains about draught and higher energy consumption for the ventilated air. One approach to solve this conflict is to use *Demand Controlled Ventilation* (DCV).

Demand Controlled Ventilation

We talk about Demand Control, when the ventilation rate for a room is governed by airborne contaminants. One can have an automatic DCV system, in which the airflow rate is governed by an automatic control device. Or one can have a manual DCV system, in which the airflow rate is governed by the user (a person acts as an indicator).

One has to be aware of the fact that, depending on a given situation, DCV should only take care of emissions of occupants and emissions according to activities in a room. As Fanger has shown, occupants and occupant related emissions can be only a small percentage of sources inside a building; there are often other sources e.g. filters, ducts, walls that may cause the real problems. The diverse pollution sources are not DCV specific; they apply to every ventilation system and building. Before installing a DCV system the designer should carefully examine the location and quantity of pollution sources with regard to occupants and other subjects. This is necessary to quantify the improvement of IAQ by a DCV system. A sick building cannot be cured with a DCV system.

The decision towards DCV should be made with regard to all pollution sources. DCV systems are likely to be cost-effective, when the emission rate of sources is unpredictable and with high fluctuations.

In dwellings often ventilation systems are not designed to cover peak loads. They usually run on a constant air exchange rate between 0.5 and 1.0 h^{-1}. Here a DCV system can lead to a better IAQ, as the peak flow rate can be designed to be above the usual flow rate, as internal supply airflows can be linked to one room without increasing the total air intake.

Detailed observations in auditoria and kindergarten proof, that ventilation systems often run on full speed regardless whether the room is fully occupied or not. Time control often failes, because the time schedules change and the real person load is difficult to predict. Presence control is only applicable in rooms with very low changes in occupancy. Manual control turned out to be nearly always insufficient. To operate a ventilation system according to the quality of air would therefore be a promissing way to cover both: good IAQ and a minimum of energy consumption.

One assumption, which is made in the design of a ventilation system is, that outdoor air is always looked upon as to be fresh and clean (what in reality is not always true). The saying, that Demand Control improves IAQ, has to be used with care. As pointed out before, only an increase of supply air improves IAQ; but: if one accepts for example, a CO_2 concentration in indoor air of 800 ppm to be of acceptable quality and the current CO_2 concentration is 600 ppm, a decrease of the ventilation rate will lead to an increase of the CO_2 level and therefore to a poorer IAQ, but the air is still regarded to be of good quality as long as it's below 800 ppm. Figure 1 shows a decision diagram to check whether CO_2 control is adequate or not.

IAQ-Sensors

As mentioned above, manual control often failes, presence control e.g. in an auditorium is not a good choice, and the effective application of indirect IAQ-control via a time relay is quite limited. A direct IAQ-control is desirable.

Compared to other control parameters in HVAC systems, IAQ-control is difficult. Control of room temperature is straight forward. Some more complex is to achieve thermal comfort. This was possible, since researchers found that not only the air velocity and temperature, but also turbulence and the direction of airflow has an influence on thermal comfort. IAQ is much more difficult to control, since nobody yet knows, what IAQ is. The substances in indoor air which cause problems are numerous and listed elsewhere. They will not be repeated here. About cross

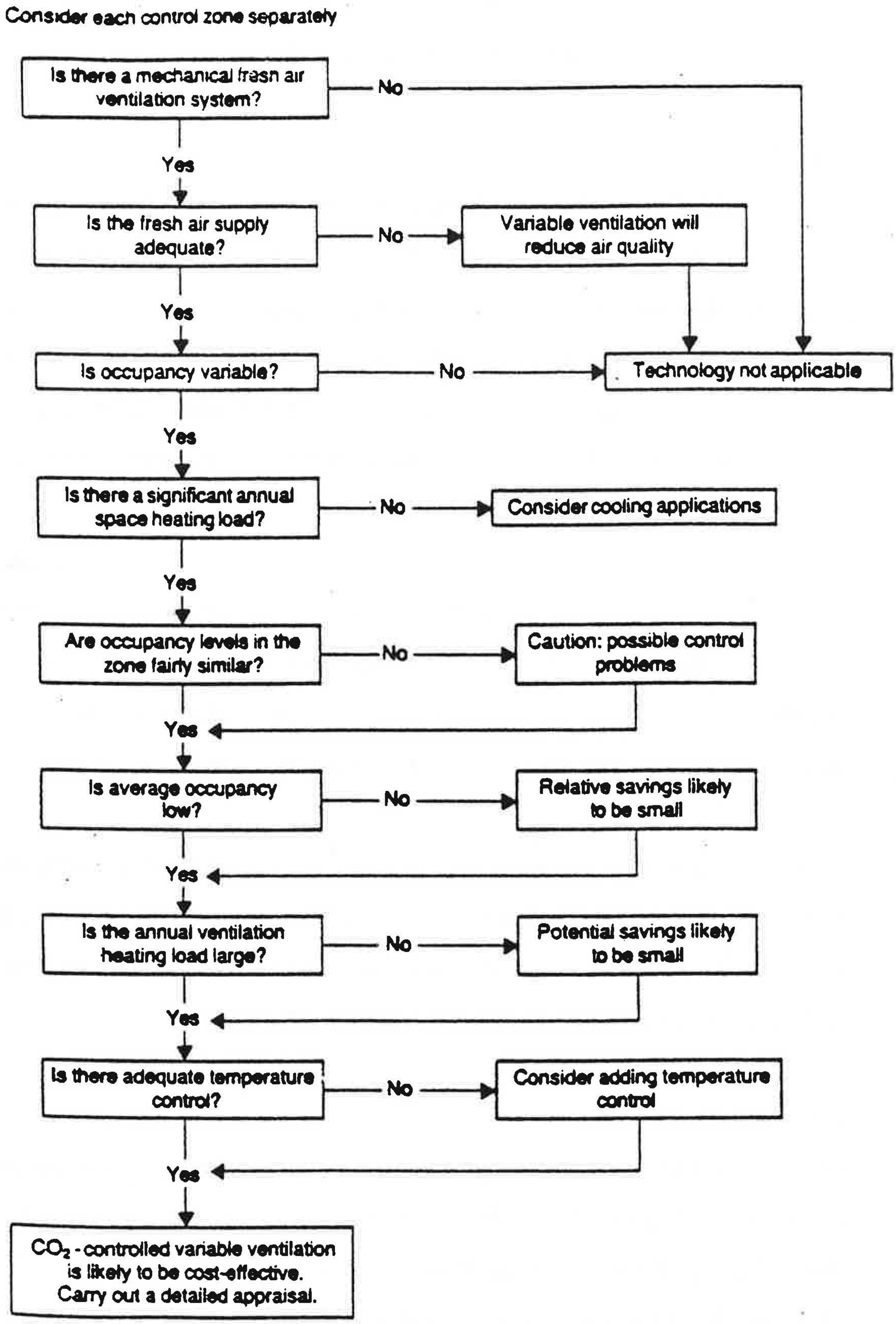

Figure 1 *Decision Diagramme for Suitability of CO_2 controlled variable ventilation (from: Annex 18, State of the art report)*

influences almost nothing is known. In a first approach, a rugh classification of pollutants with regard to Demand Control can be made within 3 classes:

Humidity

Of main concern in dwellings in European Countries are moisture damages, which deteriorate the building fabric. The growth of mould leads to allergenic reactions and health risks. Appropriate actions (better insulation, adequate occupant behaviour, humidity controlled ventilation) solves this problem. As occupants emit odours **and** water vapour, the control of room air humidity also leads to some extend to an improvement of IAQ in general, as increased ventilation always leads to better IAQ.

CO_2

Low energy houses are usually of very good insulation quality. The likelyhood of moisture problems is reduced and other pollutants will play a more dominant rule. One attempt to cover other airborne pollutants is to look for surrogates or indicators of IAQ, which are more easily to measure than the pollutant itself.

Carbon dioxide is almost accepted to be a reliable indicator for emission of humans, if they do not smoke. The detection of CO_2 with a CO_2 sensor is state-of-the-art. There are sensors on the market which selectively measure CO_2 between 300 and 2000 ppm with an accuracy of ±100 ppm. Prices range from 700 to 2500 $.

Mixed Gases

Mixed-gas sensors don't selectively measure one gas, they show responses usually against numerous gases. The sensitivity of mixed-gas sensors often corresponds to a chemical group of compounds: oxidized gases, non-oxidized gases, etc.
There are 10 to 15 mixed-gas sensors on the European market. They are sold under names like IAQ-sensor, odour detector, smoke sensor, CO sensor. They all use sensor

elements from the Japanese company Figaro. 3 different sensor element types are to be found in IAQ-sensors. Due to a different heating voltage, different amplification and other electric circuits they show very different performances against gaseous substances in the air.

CO_2 versus mixed-gas sensors

Discussions about CO_2 vs. mixed-gas sensors are very actual today, not only between sensor manufacturers but also in the research world.

Arguements pro CO_2-control are, that

- CO_2 can be selectively measured
- CO_2 correlates with emission of occupants
- CO_2-sensors can easily be calibrated.

Arguements against CO_2-control are

- no unique relationship between CO_2 and air quality, sensed by the human nose
- dominant gases which determine the level of odour sensed by the nose vary in space and time.

This leads to the opinion that selective measurements are only a very small part of the truth and a non-selective measurement allows to have more constituents under control. In general, mixed-gas sensors react quite sensitive against tobacco smoke. In rarer cases they also react against body odour, but very less sensitive than against tobacco smoke.

Calibration is often heard to be an arguement against mixed-gas sensors, because there is no defined value against to calibrate. On the other hand, a mixed-gas sensor is an attempt to simulate the human nose. Why not take the nose, if IAQ is poor and turn the knob of the sensor to higher sensitivity, til an appropriate setpoint is found?

Mixed-gas sensors show a good reaction against carbon monoxide, a hazardous odourless gas. Therefore, an increase of CO inside a building would cause the ventilation system to increase the flowrate. If the CO source is inside, the use of an mixed-gas sensor would lower the health risk to occupants. The sensor test reveilled another fact: during testing of sensors in a climate box with fixed airflow rate the mixed-gas sensors suddenly reacted. The reason was, that always around 4pm the employees of the testing institute left in their cars. The carbon monoxide of the exhaust gas of the cars migrated via the ventilation system into the building. In this case a mixed-gas sensor would have reacted in a wrong way; an increased airflow rate would worsen IAQ. In this respect however, the checking of fresh air intake could be another application for mixed-gas sensors.

Keeping the various advantages and disadvantages of CO_2 and mixed-gas control in mind, the performance of sensors has to be looked at. The IEA-Annex 18 sensor test reveilled, that mixed-gas sensors are very sensitive to changes in r.h. of the room air. Sometimes they seem to be more sensitive against humidity than against VOC.
Figure 2 shows the performance of 6 tested mixed-gas sensors when, at constant temperature of 20° C, the r.h. increases from 40% to 60% and decreases again to 20% at 10° C. The change of the output signal of all sensors is substantial. To use such a sensor for ventilation control is not recommended. The mixed-gas sensor IAQ 1 showed no humidity drift but this sensor also showed no reaction in a smoking room with 30 smokers present.
CO_2 sensors are more expensive, but have low cross sensitivity with little temperature and humidity drift.
From a total of 17 sensors tested during the environmental test (9 humidity-, 2 CO_2-, 6 mixed-gas sensors), one was destroyed by the dry heat test at 55° C. Dry cold and humidity was o.k. for all sensors. The vibration test killed 4 sensors. Transient burst

killed a couple of sensors, electrostatic discharge killed one. At the end 2 humidity sensors and one mixed-gas sensor survived the test.

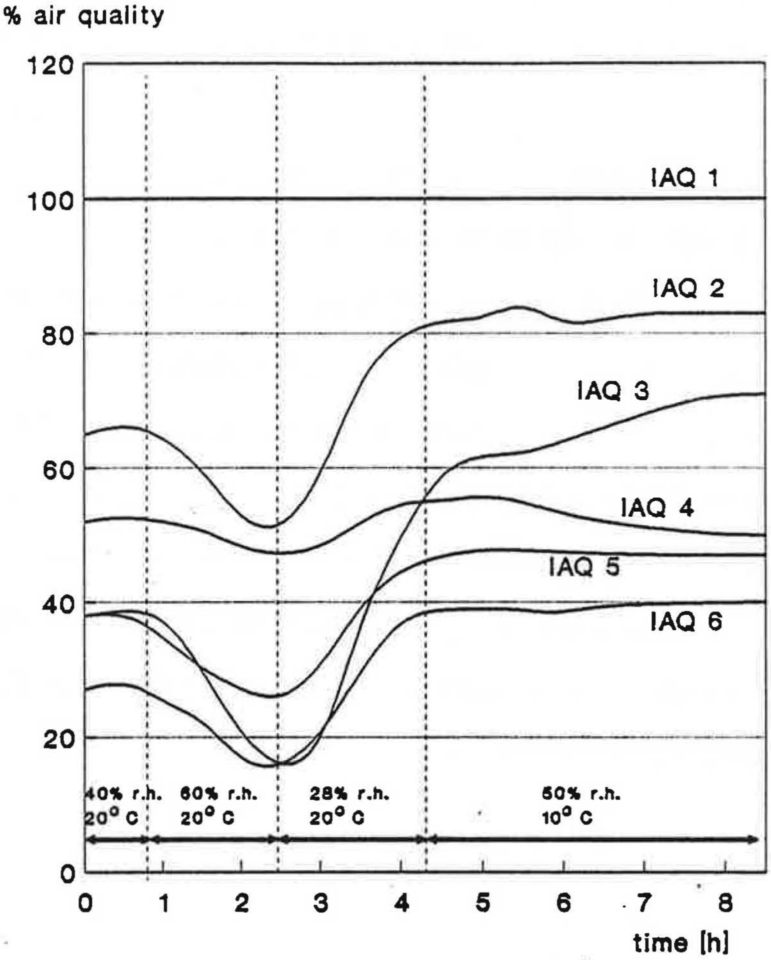

Figure 2: Drift of mixed-gas sensors against humidity changes IAQ1-IAQ6 represent sensors from different companies

The unpredictability of the reaction of mixed-gas sensors makes its application to an experiment. Humidity dependance and long-term drift are facts. Today mixed-gas sensors are installed with success in pubs and restaurants, preferably for tobacco smoke control.

Discussion

Although big efforts are currently undertaken by some companies to improve the performance of mixed-gas sensors, there is one fact that makes all further research questionable:

> How can an IAQ-sensor be developed, if no sufficient definition exists, how IAQ is defined in terms of compositions and concentrations?

Necessary requirements for further developments are, that indoor air constituents and their compositions are investigated with respect to the perception of the human nose. IAQ-sensor developments can only make progress when IAQ is a defined and measurable quantity. Sensor companies of today are able to develop every gas sensor which is demanded; however the necessary assumption is, that the performance of such a sensor is specified. Side effects and cross sensitivities can electronically easily be compensated, multi-sensor elements are on the market but without detailed knowledge of IAQ any progress in this field will be by accident.

Summary

The prerequisites for installing a Demand Controlled Ventilating System have been discussed. Other control strategies like time relay control, presence control, and manual control have been briefly commented. Direct IAQ-control with gas sensors is outlined. It is focussed on humidity, CO_2, and VOC-control. Sensor performance has been discussed as well as the problems in future IAQ-sensor development. The conclusion is that IAQ has to be investigated in much more detail. One goal should be to quantify IAQ in terms of constituents and concentrations with regard to the perception of the human nose, not only for single substances but also including influencing effects among substances.