OPTIMUM VENTILATION AND AIR FLOW CONTROL IN BUILDINGS

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Synopsis

Air quality, air flows in buildings, and ventilation are most important topics. Good air quality is however critically dependent also on other things than ventilation, e. g. source strengths, as is well known. The theme of our conference could also lead to the assumption that there is a simple connection between ventilation and air quality. As the public tend to see ventilation systems as responsible for bad air quality, it is important to state that there is no general criterion for good air quality possible to use in practice to control ventilation processes. Automatic ventilation control is still possible in specific cases only.

The ventilation process depends on the total air exchange in the building, which is difficult to control. A related question is: what is acceptable as ventilation air? Is air leaking in through the outer wall acceptable? Is air supplied through the staircase acceptable? To answer such questions air quality criteria are needed too.

1. Introduction

The original meaning of "ventilation" is: "expose to the wind." The original purpose was:

- to cool when necessary by letting warm air out and fresh air in
- to clean room air when necessary by letting polluted air out and fresh air in

This original meaning of "ventilation" related naturally to outdoor air, which was "fresh." Ventilation efficiency, for clean supply air the quotient between the concentration of pollutant in the exhaust air and the mean concentration in the room, thus is defined for pollution sources in the room. Today, it is of course no longer obvious that outdoor air is "fresh." Exchanging the air in a building is no longer a certain method to improve indoor air quality.

Indoor air quality depends on

- the strength of pollution sources in the room and, if applicable, the effectiveness of local exhausts
- the quality of supply air and other air entering the room
- the rate of air exchange
- the quality of air exchange: ventilation and air exchange effectiveness

To improve air quality in a room, source control should be the first priority. Potential sources are processes, tobacco smoking, furniture and carpets, building materials, chemicals and detergents, and more. Then the quality of the air entering the room should be checked. Do supply air or leak air transport pollutants into the room? Also here there are many possibilities: exhaust gases from traffic and environmental pollutants in the outdoor air, emissions from neighbouring buildings, radon from the ground, mould from the ground or the building itself, pollutants from neighbouring rooms, pollutants from the air handling system, and more. The quality and rate of air exchange should then be considered. Is there any short-circuiting of air from supply to exhaust? Are there badly ventilated stagnation zones creating air quality problems? Is there unnecessary recirculation of pollutants in the room? Should a controllable air flow rate be changed?

Indoor air quality is of course no stationary matter. Room conditions as air exchange efficiencies depend much on air convection, changing with the thermal loads during the day. Outdoor conditions, building status and use, building and mechanical system maintenance are examples of important factors subject to change. Proper means for building users to change, control (or at least influence) the ventilation process and system should be provided. Proper maintenance is most important, and to achieve this is the responsibility of the building management but also of the designers. Energy, flexibility, and economic aspects provide together with comfort and noise criterion's boundary conditions for the engineers. The goal is healthy building users, satisfied with their indoor climate.

The aim of this paper is to discuss the possibilities to control air quality with ventilation, to control ventilation with air flows, and to control the air flows in a building.

2. Air flow control

The resulting air flow in a building depends on
- building size and design
- temperature differences between the air in the building and outdoor air
- wind forces around the building (which forces also depend on the surroundings)
- the distribution and size of openings and leaks at the building perimeter
- the distribution and size of openings and leaks within the building
- ventilation openings, ductwork, and fans; ventilation strategy and control

Within a single room the flow depends on
- convection currents (temperature differences)
- air flows from air terminal supply devices and other openings letting air in
- the location of air terminal exhaust devices and other openings letting the air out
- the room users

Most of these factors vary, rapidly or slowly: outdoor temperature and wind, the distribution of open doors and windows, leak areas, temperature differences within a room or between rooms, and the use of the building and it's rooms. To make control of the resulting air flow easier one can try to minimize these influences: entrance lobbies, windows that cannot be opened, very tight buildings, mechanical ventilation systems with big pressure drops or constant flow devices in order to minimize weather dependence, and more. However, many such measures tend to decrease the freedom of the building users and make them experience ventilation as a burden, not a benefit. Poorly deigned, constructed, or maintained systems enhance of course this impression, creating a lack of trust. Many ventilation engineers work in "wakes" of such experiences. Another strategy is to use the factors that can be controlled to compensate other influences. This is of course the same strategy as most building users have when they open windows. Consequently, also this strategy must be used with care, not to decrease the freedom of the user. It is also only too easy to make such systems complicated, or at least appear complicated to the user.

The air flow in a building depends on the ventilation system. A mechanical supply-exhaust system tends to control the flow rates, the indoor pressure has to adjust. Mechanical exhaust systems decrease indoor pressure. "Natural" ventilation systems tend to induce pressure differences, flow rates depend on opening sizes. Only systems with mechanical supply air allow a direct control of distribution of ventilation air to rooms, at least part of it, so minimum flow rates can be reached at "all times." Exhaust and "natural" ventilation systems depend on the distribution of openings, that is ventilation openings, open doors and windows, and leaks. The area relations between the openings decide the flow rates. An open window, creating a big flow area compared with other openings, can "steal" all the ventilation air, leaving other rooms very poorly ventilated.

This short discussion illustrates the difficulties to control air flows in buildings. Evidently only part of the total air flow can be controlled, how big depend on the system design, on building tightness, on window openings and other building use, and on the efficiency of the maintenance organization.

3. Ventilation control

What is "ventilation air?" Supply air can be defined as air intentionally let into a space or a room, through terminal devices connected to ductwork or through openings intended to allow inflow of outdoor air. Exhaust air can be understood as air leaving a room or space, through terminal devices connected to ductwork or through openings intended to allow outflow of room air. But air entering or leaving a room otherwise also takes part in the air exchange, as measured with conventional tracer gas tests. Then, what is acceptable ventilation air? Is air that has leaked into a building through an outer wall acceptable? Obviously not always but when? Is air supplied through the staircase of an apartment house acceptable or is it only contaminated leakage air? Studies show (Herrlin, 1992) that in some cases such air represents a big part of the total air exchange in a flat.

The answer to such questions is: it depends on the air quality. Many excellent studies have been made to define criteria for the air quality (see proceedings from the conference series "Indoor Air" and for instance Cain et al 1995), but criteria feasible for ventilation control seem to exist only for specific cases, as CO_2 concentration as a measure of body odour. The difficulties regarding the quality of supply or other "ventilation air" are similar: only criteria for specific contaminants can be established and continuously controlled, allowing no general guarantees for good air quality. This is also true for sensory olfactory measures, although these have the benefit of direct aiming at user satisfaction. During later years the quality of mechanically supplied air has been questioned, which of course emphasizes the problem.

A traditional strategy is to prescribe minimum air flow rates for health (which hopefully not should be taken as maximum flow rates when energy auditing). Such flow rates have an empirical background and cannot be expected to work when new technologies, materials, processes and practices are introduced. The ventilation engineer cannot guarantee the air quality.

5. Discussion

Air quality depends on many factors, ventilation is only one. Ventilation is a process combining influences of the efficiency of air exchange, transport of air contaminants, and the quality of air entering the room or space. Air flows and air exchange in the building depend on many other factors than the ventilation system, as have been previously discussed, and are difficult to control. Ventilation control is not possible without an air quality criterion. Therefore, automatic ventilation control is still feasible in specific cases only.

Often ventilation is described or mentioned in such a way that it appears to the public as the key to good air quality. Then ventilation also gets the blame when air quality is bad, although the reason can be new sources of pollution, changed traffic conditions outdoors, or similar. The ventilation community must make the limits and possibilities of their technology clear. In practice, a ventilation system transports air flows at specified rates (within some limits). Noise criteria should be met. For supply systems, supply air quality should be only marginally lower than outdoor air quality, and with fewer particles. Supply and exhaust terminal devices should be chosen so criteria for draught and comfort not are violated, and so air exchange and ventilation efficiencies are acceptable. This is what should be expected of the ventilation system. In the design stage, the ventilation engineer should of course take active part in decisions about system air flow rates, and has also an obligation to work for flexibility and preparations for control and maintenance.

The aim of ventilation is good air quality for the building users. The designer of ventilation systems therefore is critically dependent on good indoor air quality criteria. The interaction between the building users and the ventilation system is also a key issue: the system must allow user influence on performance and control. The system should also be flexible, to meet varying demands. Studies about the relation between ventilation and air flows in buildings, and about the controllability of such air flows thus are very important to investigate the limits for this freedom.

References

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