OCCUPANT INTERACTION WITH VENTILATION SYSTEMS

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PAPER 1

REQUIREMENTS FOR ADEQUATE AND USER-ACCEPTABLE VENTILATION INSTALLATIONS IN DWELLINGS

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SYNOPSIS

Before 1970 the ventilation of dwellings was considered a thing hardly worth thinking of, because it took place more or less satisfactorily in the then generally rather untight buildings. Besides, far lower numbers and quantities of hazardous chemicals were employed in building materials and households then than they are today, and measuring techniques were not developed.

After the oil crisis of 1973, ventilation was discovered as a main source of energy losses. Consequently, strong efforts were made and successes could be claimed in reducing the ventilation losses through airtightening of the buildings.

The next phase in the ventilation scene - the one in which we still find ourselves today - brought up the additional topics of hygienic indoor air quality and condensation problems. Control of both problem areas requires action on two fronts: on one side against any avoidable inside pollution sources and on the other side against excessively low ventilation rates.

After years of intensive studies on indoor air pollution sources, pollution levels, condensation effects, building airtightness, and air change rates, we are now at the point to discover that no solution whatsoever to the ventilation problem is possible if compatibility with user comfort and user habits are not properly taken into account. User compatibility of a ventilation strategy under todays conditions in dwellings must in fact be understood as a requirement equivalent to the purely functional ones of pollutant removal and of economy.

It is tried in this paper to summarize on the general requirements for user compatibility, the latter having been widely neglected so far. Features of improved systems are given.

1. FUNCTIONAL ADEQUACY

A ventilation system - be it of the natural or of the mechanical kind -must be functional, that means it should fulfill its duties properly. Some of the duties are in competition with each other, so that compromises are to be made.

First of all there are the requirements which are the very justification for ventilation at all:

1. fresh air supply to occupants
2. removal of pollutants
3. dehumidification
4. combustion air supply (if applicable)
5. odour removal.

Then there are "secondary" functional requirements, aimed at making ventilation affordable and feasible:

6. energy conservation
7. cost effectiveness
8. retrofit ability.

The first group of requirements is satisfied all the better of course, the higher an air change rate is established. For the second group the contrary is true.

But the air change rate is only one parameter of influence on the removal of harmful or unwanted components in the room air. The second parameter is the air circulation pattern in a ventilated space. In the mechanically ventilated space of fig. 1a for instance, rather good mixing of the space air is obtained, providing equal pollutant distribution at any point in the space. With pattern b, and the same flow rate, most of the ventilation air bypasses the lower part of the space, failing to remove pollutants originating from there. In fig. 1c, a displacement-like ventilation pattern is obtained resulting in very good pollutant removal effectiveness for all locations in the space which are not lying downstream of a pollution source, a point which is to be elaborated on an individual basis in the particular case.

The common definition for the pollutant removal effectiveness is illustrated e.g. by Sandberg (1):

$$\varepsilon = \frac{\text{overconcentration exhaust air}}{\text{overconcentration entering air}} = \frac{C_e - C_o}{C_{ri} - C_o}$$

The indices of C mean:

e	exhaust air
o	outside air
r_i	room air at location i in the space.

For case a (complete mixing) $\varepsilon = 1$ is obtained: Ventilation schemes today in use show a rather poor effec-

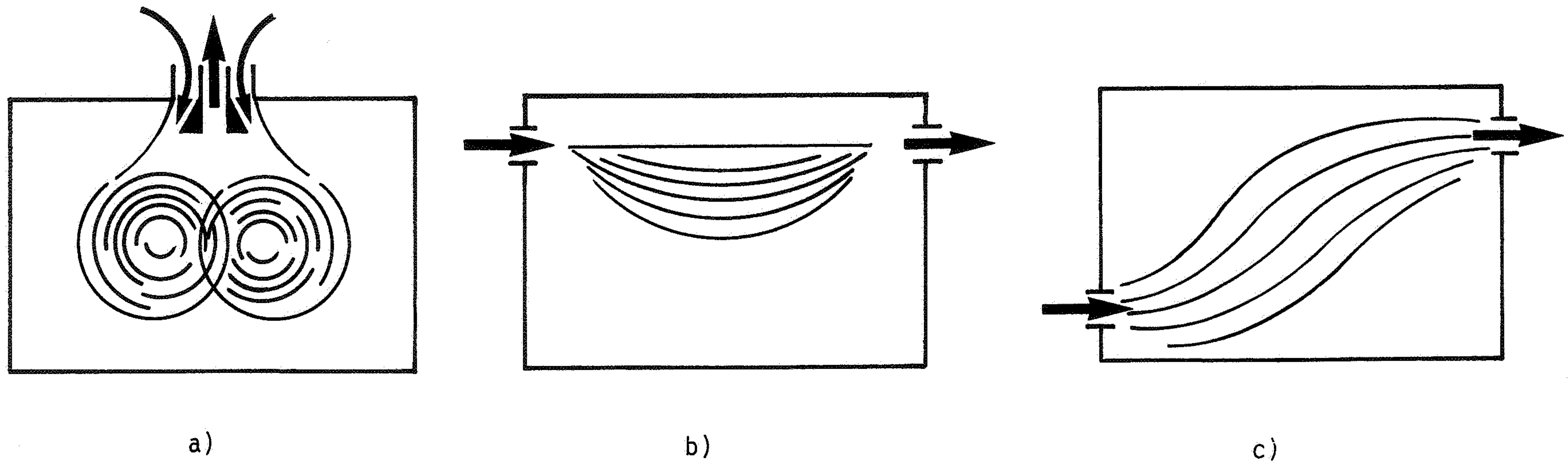

Figure 1: Different ventilation systems result in different ventilation efficiencies

tiveness (this holds true not only for window ventilation), ranging often around 1 or below.

Ventilation effectiveness is **the** key to systems compatible with both requirements 1 ... 5 (pollutant removal and fresh air supply) and 6 ... 7 (energy and cost economy). It deserves far more attention than it is generally paid today, and offers ample room for the development of more effective systems. AIC Technical Note 17 (2) gives a good resumeê and bibliography on ventilation strategies though it does not include publications after 1983 such as e.g. (3) or (5).

Another important point with any improved ventilation system is retrofitability. In Germany for instance, the average age of a residential building is about 70 years. Therefore if real progress is to be made in the ventilation scenario within a foreseeable future, high priority must be given to retrofits.

In dwellings equipped with flued combustion appliances (fireplaces, stoves, gas boilers etc.) compatibility of those appliances with the ventilation system is to be established. No extract-only ventilation is then allowed (not even a range hood!) and the building envelope untightness should be at least in the order of 15 m^3/h at 50 Pa per kW heating load of a stove (open fireplaces require a considerably higher untightness).

A particular case are radon emissions from the soil. No mechanical extract-only ventilation systems are allowed in such cases. Instead, slightly overpressured combined exhaust and supply systems will perform best and prevent radon from entering the ventilated space.

2. USER COMPATIBILITY

Functional adequacy of a ventilation system is one requirement, but as already outlined, user compatibility is a necessary completion. Experiences within the German research programm "Ventilation in Residential Buildings" ("Lüftung im Wohnungsbau") (4) and with other investigations have shown, that there is indeed a high probability of inhabitants rejecting or of conteracting ventilation systems which do not comply with users expectations.

Regarding user compatibility, rather low marks had to be given to most natural and mechanical ventilation systems. Natural ventilation requires to much attendance and offers poor control options. Main complaints of nearly every mechanical system concerned noise and draught.

The following requirements are to be satisfied in order to comply with users expectations:

9. avoidance of draught effects
10. tolerance of ill-attendance
11. minimal maintenance requirements
12. low noise level
13. freedom to interfere
14. familiarisation with a system

Requirements 13 and 14 refer to psychological rather than to physical sensations of a user, which nevertheless are often decisive for acceptance or rejection of a system:

- the user should never feel oppressed by a ventilation system, but always have the feeling of freedom of interference

- the great majority of people are rather conservative in their habits, thus appropriate instruction and motivation is a must with any new techniques.

Requirements particularly critical with natural ventilation systems are (in the order of importance) 10, 9, 11, whilst with mechanical systems 9, 12, 14, 13, 11 have priority.

3. FEATURES OF IMPROVED NATURAL VENTILATION SYSTEMS

In the previous section on functional adequacy it was shown that maximizing ventilation effectiveness is the most promising option to reconcile the contradictory requirements of pollutant removal and economy. Because maximizing ventilation effectiveness allows air exchange rates to be reduced, and because draught and noise effects have a strong correlation with flow rates, user compatibility too benefits from improved ventilation effectiveness. Indeed: **for the design of any ventilation system its effectiveness is of ultimate significance** under almost every aspect and should be given first priority.

Tolerance of ill-attendance is a hard task to fulfill with natural ventilation systems, if energy economy is to be observed. Some kind of automatic control of the opening cross sections seems unavoidable (controlled natural ventilation). In its simplest form this could mean windows or ventilation openings controlled by the outside temperature. Probably better would be a feedback control system with the humidity (in dwellings) or carbon dioxide (CO_2) (in public buildings) as controlled variables.

If automatic control is considered too much an expense but users proper attendance expected to be a thing one can count on (previous experience does not prove that), considerable improvement on the opening mechanisms of present natural ventilation devices and intensive instruction campaigns to the public on adequate ventilation behaviour will be a prerequisite.

Improved natural ventilation systems should have the following features:

- windows or ventilation openings should be located so that displacement ventilation is supported and no draught felt in the main occupational zone of rooms

- preferably automatic control of the opening cross section of at least one ventilation device should be provided; outside temperature or (better) humidity or CO_2 should be the controlled variable

- manual control of the opening cross section to be provided in discrete steps with markers specifying the room size ventilatable under reference conditions in the respective position

- ventilation openings to be arranged always in pairs, with maximum vertical distance (one above floor, one under ceiling) to exploit the stack effect in the absence of wind as driving force

- contamination effects of ventilation openings should be minimized, easy cleaning made possible by suitable design

- in spaces with flued combustion appliances, a defined building untightness should be established as specified above.

4. FEATURES OF IMPROVED MECHANICAL VENTILATION SYSTEMS

What had been said about ventilation effectiveness with natural systems holds also true for mechanical systems: the higher the effectiveness, the lower the flow rates allowed, diminishing the problems of draught, noise, heating and auxiliary power demand, and equipment size (cost!).

In spite of the fact that with mechanical systems a good ventilation effectiveness can be established much more easily than with natural systems, most systems investigated in (4) and in other research works had severe shortcomings. Main complaints were with regard to:

- draught effects
- noise level
- odour transmission from kitchen/bathrooms
- equipment contamination and no regular service provisions
- design ratings not established
- high auxiliary energy consumption
- user has no interference option (feels oppressed)
- interference with combustion equipment.

In general, solutions with single fans for individual rooms should be avoided with mechanical ventilation systems and central systems be provided instead integrated into the entity of all hydraulically coupled rooms. Otherwise low ventilation effectiveness, poor economy and lack of comfort are programmed.

Two risk situations deserve particular attention: if either radon problems exist or if flued combustion appliances are used in the space under consideration, no exhaust-only ventilation is allowed. Combined supply-and-exhaust systems are then to be used instead working with small supply air excess, providing an overpressure of a few Pa in the ventilated space.

From the point of view of ventilation effectiveness (displacement ventilation to be aimed at) as well as from physiological effects (overheated air is felt "stale" and "not fresh") it seems necessary to avoid overheating of the supply air with ventilation systems.

In order to obtain an effective, economical, and comfortable (and thus user-accepted) ventilation system, the following points should be considered with system and equipment design:

System Design

- restrict design ratings to base requirement (windows for peak load)
- supply air inlets at low level (out of direct occupational zone)
- large cross section of inlets for low air velocity
- avoid occupational zones downstream of pollution sources
- supply air temperature slightly below average room temperature
- exhaust-only systems require properly located supply air inlets
- exhaust air outlets at ceiling of rooms and close to contamination source
- filters required for every air intake
- system should work properly without attendance
- offer manual interference **option** (acceptance!)
- compatibility heating/ventilation system to be evaluated
- acceptance test for every installation

Equipment Design

- satisfactory efficiency of ventilators/motors
- available units not be overrated for average dwellings (100 m^3/h and below required)
- use air ducts and air inlets with low hydraulic losses (noise, power)
- warning light for filter contamination
- filter cleaning procedure to accommodate user
- complete module for simple and low cost installation
- units for retrofits required
- design for more cost effective production.

5. CONCLUSIONS

With new building materials and with todays often excessive use of household chemicals pollution sources in dwellings have multiplied. New construction standards and restrictive ventilation habits of the occupants as a consequence of energy conservation efforts on the other side have reduced natural ventilation rates in buildings, sometimes below a level sufficient for pollutant or water vapour removal.

As a consequence, mechanical ventilation systems have found widespread introduction in a number of countries, whilst little effort has been spent on the improvement of natural ventilation devices. It is obvious, that occupants comfort and acceptance has so far not found appropriate consideration with the design of ventilation systems of any kind.

If real progress is to be made regarding indoor air quality the following points must be given much more weight in future:

- ventilation effectiveness
- integrated system approach:
  - o pollution removal
  - o energy conservation
  - o comfort
- improved natural ventilation devices
- retrofit ability.

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