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AIR QUALITY AND ENERGY CONSERVATION BY DIFFERENT VENTILATION STRATEGIES

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SYNOPSIS

The increasing awareness that indoor air quality aspects may restrict energy conservation by infiltration and ventilation measures has led to extensive investigations of different ventilation strategies. Aiming at a reduction of energy consumption air infiltration and ventilation rates have to be minimized. But in order to maintain healthy, safe and comfortable conditions for the inhabitants and to avoid damages to the building fabric the outdoor air supply should not remain under minimum ventilation rates.

To find out advantages and disadvantages of various ventilation systems, to assess the role these systems will play in different ventilation strategies and for defining ventilation standards in the Federal Republic of Germany in 1980 the main activities of a r & d programme "Air Infiltration and Ventilation in Residential Buildings" had been started, supported by the Federal Ministry for Research and Technology.

First results show that the conflicting requirements energy conservation and adequate indoor air quality in many cases best are met by mechanical ventilation and heat recovery. In unoccupied test houses as well as in occupied buildings the total energy consumption coul be reduced by 10 to 20 %. Inhabitant's behaviour and functional deficiences of the systems can decrease these effects in practice.

1. INTRODUCTION

The basic aim of the German r & d programme "Ventilation and Air Infiltration in Residential Buildings"[1] was to identify possibilities for reducing ventilation heat losses. Therefore emphasis had been laid on investigations of different ventilation systems in unoccupied test houses as well as in occupied buildings. From the beginning it was evident that aspects of indoor air quality had to be incorporated because reducing ventilation rates resulted in higher levels of indoor air pollutions' concentration. Of importance in this connection are the activities of Annex IX "Minimum Ventilation Rates"[2] of the International Energy Agency. To maintain healthy, safe and comfortable conditions for the inhabitants on one hand and to conserve energy on the other the various ventilation systems will play different roles in ventilation strategies being of importance for residential buildings.

Table 1: Reasons for ventilation and measures for acceptable indoor air quality

	minimum ventilation rates*	ventilation strategy	primary measures
i) avoid damage to building fabric	0.8 ach**)	basis ventilation	ventilation
ii) decrease annoyance	0.6 ach	add. ventilation dependent on number of persons	ventilation
iii) minimize health risks	> 0.5 ach	add. ventilation supporting other measures	reducing or prevent emission (covering, elimin. materials etc.), air cleaning

*) order of magnitude, assumption: floor area 70 m^2, 3 persons

**) climatic conditions and building construction typical for Germany

In table 1 only a rough idea will be given about necessary air change rates and measures. It was and is one of the objectives of Annex IX "Minimum Ventilation Rates" and the German standard DIN 1946 "Wohnungslüftung" to define and to give reasons for ventilation rates in more detail.

Important is that building physics, inhabitants' health and annoyance demand minimum ventilation rates[5] above 0.5 ach. Possibly in Germany moisture aspects dominate and minimum ventilation rates in the order of 0.8 ach have to be recommended[6].

2. SOME ASPECTS OF INDOOR AIR QUALITY

The principles of improving indoor air quality by ventilation are based on dilution and removal of contaminants. Known for decades the discussions on fundamental problems still continue:

- definition of the term "sufficient indoor air quality"
- outdoor air rate needed to ensure this indoor air quality
- ventilation strategies which are most appropriate for an effective contaminant removal (ventilation efficiency).

Most of the national ventilation standards are confronted with these questions. In Germany e.g. activities are going on to modify existing standards, having in mind air quality as well as energy conservation.

There are three reasons of different kind for the observance of minimum ventilation rates in buildings and dwellings:

i) to avoid damage to the building fabric

typical indoor pollutants: moisture and humidity

ii) to decrease annoyance of the inhabitants

typical indoor pollutants: odours, body odour, carbon dioxide etc.

iii) to minimize health risks

typical indoor pollutants: tobacco smoke, radon, organic vapours and gases, formaldehyde etc.

The first reason is nearly independent of the number of persons living in the dwelling. That speaks for the definition of a "basis ventilation". In the second case the number of persons is to a great extent correlated with the degree of annoyance. Carbon dioxide e.g. may be used as an indicator for body odour. Influencing the emission rate is nearly impossible. So the required ventilation rate will be dependent of the number of inhabitants. Besides, Berg-Munch et al.[3] could show a different sensitivity of persons to body odour and carbon dioxide. Therefore the minimum ventilation rate will be also dependent of the percentage of persons accepting a certain air quality level. In the ASHRAE Standard 62-81[4] acceptable air quality is defined as an indoor air condition which is accepted by at least 80 % of the inhabitants.

For the definition of minimum ventilation rates in the third case a risk assessment has to precede. Apart from the question which risk level could be accepted, for decreasing pollutants' concentration ventilation only can support, independently from the number of inhabitants. In table 1 some of the statements of interest are summarized.

3. VENTILATION SYSTEMS AND STRATEGIES

The ventilation systems under consideration, their ventilation functions on principle and energy aspects had been presented in several papers[1,7]. The investigations covered

natural ventilation:

windows, devices for "controlled" natural ventilation

and mechanical ventilation:

central or decentral systems for exhaust fan ventilation or for both supply and exhaust fan ventilation, in two multiple dwellings combined with heat recovery.

The main types of ventilation systems and characteristics being of interest are summarized in table 2.

Table 2: Ventilation systems and some of their characteristics

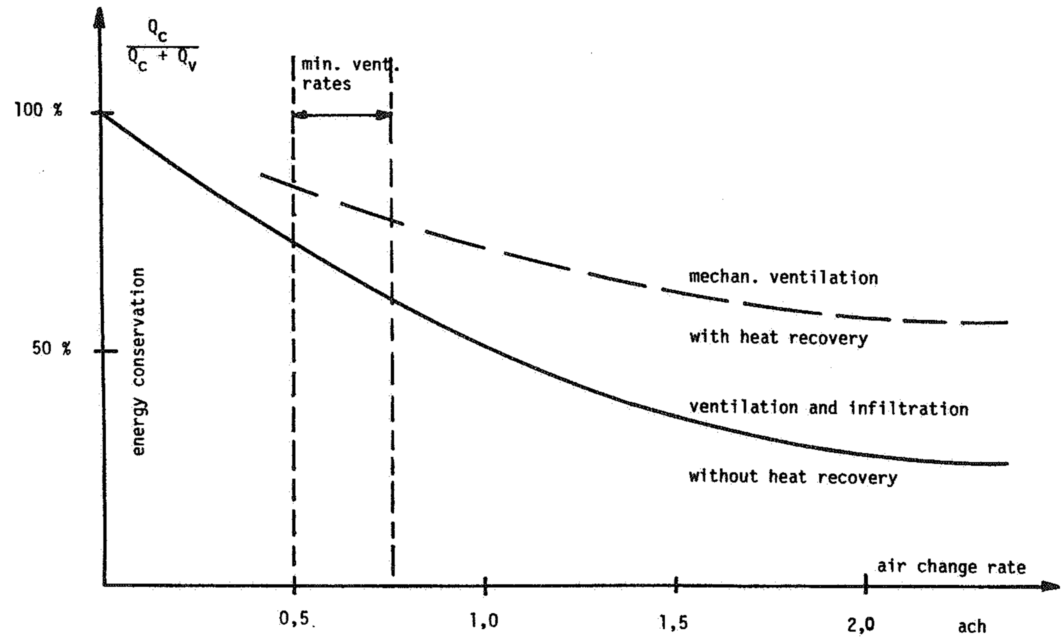
	control of ventilation rates	main influencing factors	auxiliary energy
natural ventilation	extremely variable	inhabitants, wind velocity, temp. differences	no
controlled natural ventilation	control in practice not yet proved	inhabitants	no
exhaust fan ventilation	good	almost independent	for fan operation and heat recovery
supply and exhaust fan ventilation	very good	almost independent	for fan operation and heat recovery

From the viewpoint of energy conservation the air change rates should be as low as possible, independent from other factors as wind velocity temperature differences, inhabitants behaviour etc. and controllable. For reasons of indoor air quality they should be high enough, not remain under values in the order of 0.6 to 0.8 ach, but also not affected by other factors and adaptable to changeable inner pollution concentration levels.

Comparing with the system's characteristics in table 2 mechanical ventilation systems obviously meet these demands best. For the example of a multi-story residential building different ventilation strategies and their consequences are illustrated in figure 1.

Figure 1: Energy conservation by different ventilation strategies

multi-story building with A/V = 0.7 m^{-1}, U = 0.5 W/m^2K,
Q_V: ventilation heat loss, Q_C: conductive heat loss

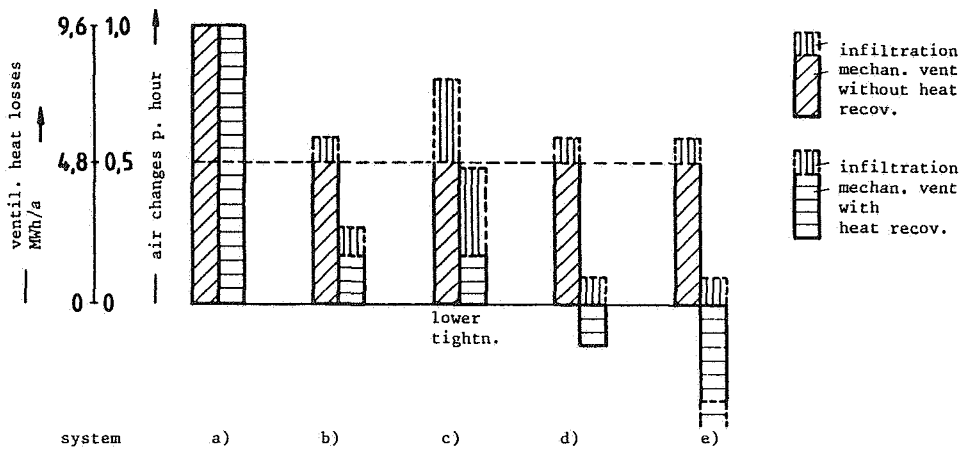


For low air change rates as e.g. in the case of tight building envelopes and tight windows energy conservation is comparatively high. However, indoor air quality can raise problems. Air cleaning devices or other measures decreasing emission rates could make such strategies to an alternative.

Higher inner loads may require air change rates far above 0.7 ach. Heat recovery is the only way to conserve energy, especially if the system's ventilation efficiency is low. In figure 2 common systems are compared.

Figure 2: Typical air change rates and heat losses by ventilation[7]

single-family dwelling, volume ca. 450 m^3
a) reference, window ventilation
b) + c) supply and exhaust ventilation, heat exchanger
d) supply and exhaust ventilation, air/air heat pump
e) supply and exhaust ventilation, heat exchanger, heat recovery from exhaust gas



High air change and infiltration rates result in high energy losses (2a and c). If these rates are necessary for indoor air quality reasons heat recovery influences positively the energy balance.

4. CONCLUSIONS

In principle supply and exhaust fan ventilation links indoor air quality and energy conservation most promizing. Ventilation heat losses can be minimized by heat recovery if the building is tight and the outdoor air flow controlled. The mechanical ventilation gives the possibility to adapt air change rates to varied situations, e.g. higher indoor or outdoor pollutant levels. These systems can be developed to pollution controlled ventilation systems.

But in ventilation strategies also other aspects have to be considered: elimination of pollution emissions, air cleaning devices, ventilation efficiency etc.. Further important factors are reliability of these technical systems, maintenance and finally acceptance by the inhabitants. So, in ventilation strategies also other system variants will play a role.

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