# VENTILATION SYSTEMS IN RESIDENTIAL BUILDINGS: REQUIREMENTS TO THE DESIGN OF SYSTEMS AND EQUIPMENT

V. Meyringer
Dornier System GmbH
D-7990 Friedrichshafen

## Introduction

Tightened directives are bringing about drastically reduced transmission losses with new and even with retrofitted buildings in Germany as well as in many other countries. It was recognized with remarkable delay, that sealing of the building envelope as the result of conservation measures together with the ever increased use of new chemicals in building materials as well as in cleaning agents and sparing ventilation habits could lead to hazardeous indoor air quality.

On the other side, as the energy losses of conventional ventilation measures (infiltration and window opening) surpass in most cases the transmission losses of a new building, excess ventilation habits cannot be afforded for economical as well as for environmental reasons. To make it evident: in Germany, energy required to compensate for the ventilation losses of dwellings is nearly equivalent to the energy consumption of all private cars.

The matter be ing much more complex with the air quality issue than with the transmission losses it is no wonder, that generally recognized ventilation standards have not been agreed on so far. Present air change rates laid down as a standard in some countries must be considered rather as a crude value, which may still cause unnecessarily high energy losses in many cases. This was done in order to provide for some "reserve" to account for the variety of possible situations.

The more obvious reason for the uncertainty in the required air change lies in the great many potential pollutants existing in a building. Their elimination should be considered a problem of the designer and of the building/chemical industry and not be transferred to ventilation - at least not with new buildings. This issue is not subject of this paper. The second reason lies in the ventilation techniques themselves: establishing a specific level of air change in a dwelling (which is in itself a tough requirement with free ventilation) does in many cases (even with mechanical ventilation) not improve the air quality in the occupational area of the dwelling correspondingly. In other words: the efficiency of ventilation is uncertain and in many cases remarkably low.

This paper evaluates outcomes of the investigation program "Ventilation in Residential Buildings" sponsored by the German Federal Ministry for Research and Technology. Its intention is to point out shortcomings of the present ventilation scene, to compile basic requirements for more efficient systems and to present some solution proposals though by no means pretending to be comprehensive. The issue necessarily includes the aspect of users behaviour, which is felt to have been neglected so far.

## Four Claims on Ventilation

A ventilation method claiming to be efficient must meet 4 requirements:

1. establish hazard-free air quality
2. comfort user

3. conserve as much energy as feasable
4. be cost effective.

Both **requirement 1 and 2 are absolutely compulsary** for any system: establishing the required indoor air quality b eing the proper reason for ventilation, the system will flatly be rejected by the user if felt not comfortable. The latter 2 requirements - though not compulsary - are highly desirable. Energy conservation from the national economist and and from the ecologist points of view, cost effectiveness is the yardstick tenants will use for their decision on an investment.

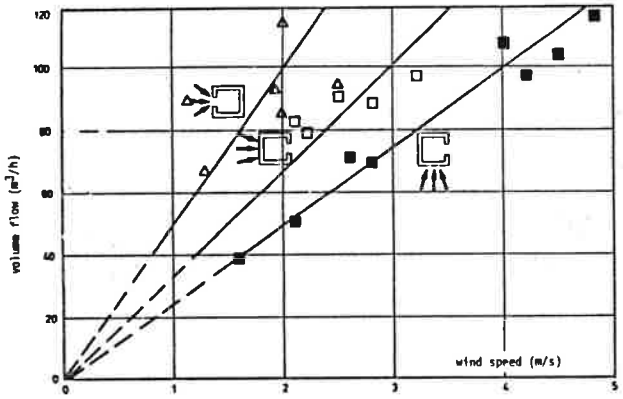
## Shortcomings of Existing Systems

The table gives a survey on the status of ventilation methods presently in use.

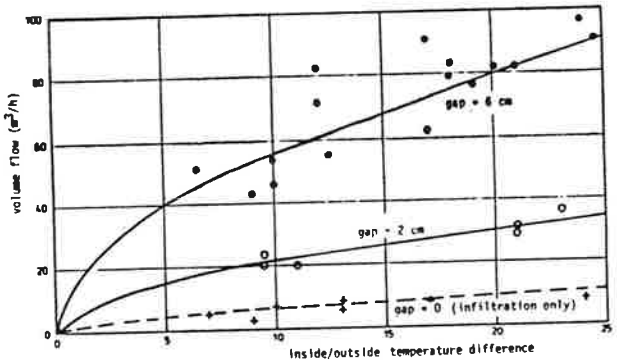
| | AIR QUALITY | USER COMFORT | ENERGY CONSERV. | COST EFFECTIV. |
|---|---|---|---|---|
| FREE VENTILATION | extremely variable (tightness, wind, temper. user habit) | low (attendance, draught) | very poor (if on safe side of air change) | high (no investement) |
| SINGLE ROOM VENTILATION | depends on air entrance location | low (noise,draught, odor infiltr.) | rather poor (low efficiency) | low (numerous units) |
| CENTRAL EXHAUST SYSTEMS | depends on air entrance location | moderate (draught) | moderate (ventil. heat lost) | rather low |
| CONVENTIONAL SEX-* VENTILATION | satisfactory | acceptable (draugt still critical) | acceptable (heat recovery) | acceptable (heat recovery pays off) |

* supply and exhaust air with heat recovery

With **free ventilation** (window ventilation) it is extremely difficult and permanent attendance is required to maintain adequate room air quality whilst avoiding waste of energy. Permanent fluctuations of the air change rate are taking place according to the variations in wind speed and direction and in outside temperature. The figure below shows, that the exchange rate of air through a tilted window (common in German houses) is nearly proportional to

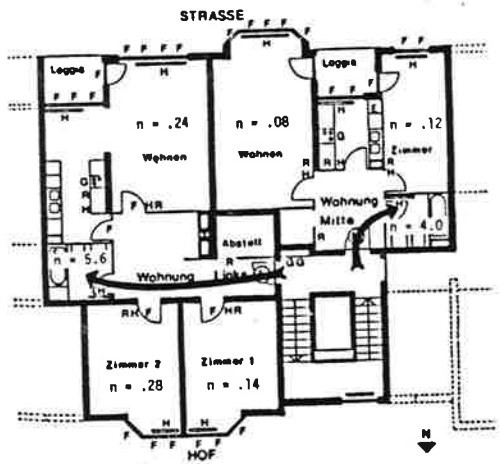




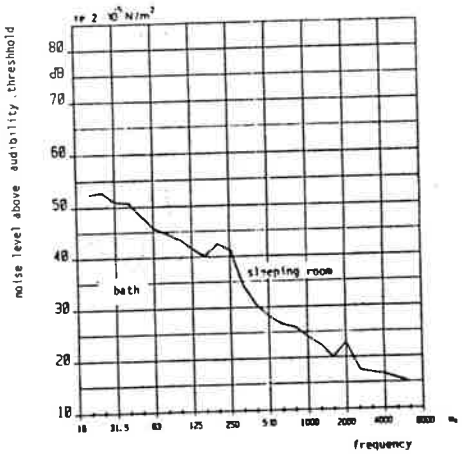




wind speed and also depends on wind direction. The dependence on inside/outside temperature difference in contrast follows approximately a square root law as shows the figure on top of this side. Obviously, depending on the double effect of wind and temperature a variation range of 1:20 or more can be achieved easily with the same window position.

Air quality and user comfort in dwellings with **mechanical systems** depend largely on the established air circulation pattern. This pattern was found to be basically a function of the location of the inlets and outlets of supply an exhaust air and of the air velocities. The figure at right represents a very common case with exhaust ventilation systems, where air infiltrates through staircase and main door into the dwelling, bypassing the living area where it is most pressingly needed (n=air change rate).




Very common complaints regard the noise level of ventilation systems. The figure at right conveys a situation with high noise level in the sleeping room, in fact is was found to be even higher than in the bath room.




Almost every mechanical ventilation system investigated was found to have more or less serious shortcomings such as:

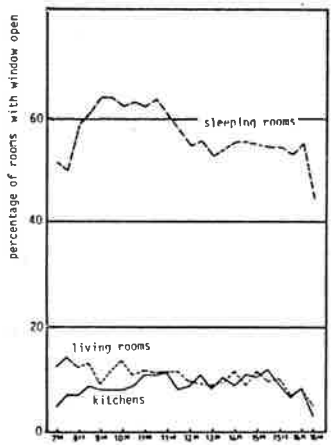
- unacceptable noise level
- severe draught effects
- high auxiliary energy consumption
- design flow rates not established
- odour transmission from bath/kitchen to living rooms
- deficient installations (no acceptance test performed)
- no maintenance provisions
- no directions given to inhabitants (thus ventilation habits remain unchanged)
- user has no interference option (feels oppressed)

## Users Behaviour is Decisive

Users behaviour has two aspects: acceptance of the ventilation options offered - a case of particular importance with mechanical ventilation - and proper handling of the ventilation installations.

**Acceptance** is a prerequisite which cannot be overemphasized. It was found that causes of all rejections were noise or draught. Consequently first priority is to be given to those aspects when installing a ventilation system, since a rejected system (with air inlets or outlets choked by the user) will never be effective.

It has been proved again and again that intelligent window **ventilation habits** cannot be expected of the average inhabitant, but that insufficient air quality or energy wasting habits are at least as common. Observation of a sample of 230 dwellings in three buildings has produced evidence, that sleeping rooms were generally ventilated throughout most time of the day (when they ar not occupied). Kitchens in contrast (main sources of vapour and odour at this time) were rather poorly ventilated (see figure at right).




Considering such behaviour (which reflects only the average and by no means the worst cases) and taking into account the unforeseeable effects of wind and temperature on the air change it becomes evident, that efficient ventilation is not feasable using infiltration and windows only. Instead some means are to be provided at least to compensate automatically for the effects of wind and temperature and possibly to spare at all the necessity of regular attendance. At the present state of the art no other satisfactory option can be seen for such a means than mechanical ventilation.

Apart from the problem of availability of suitable ventilation installations, it was found that most inhabitants even of buildings equipped with ventilation systems were not given any helpful information nor were they motivated to develop intelligent ventilation habits.

## Design Features of Advanced Ventilation Systems

Design and construction of ventilation systems presently in use and on the



market offer not only plenty of opportunity for improvement, but rather must this improvement be considered a prerequisite for market penetration.

Generally, vertically oriented displacement ventilation (coming in use in major commercial and public buildings) seems superior to conventional dilution (mixing) techniques still standard in dwellings. for a number of reasons:

- lower volume flow rates required for same air quality
- better user comfort (less noise, less draught)
- less energy required (ventilation heat as well electricity for drives).

Such "soft" systems may be considered a hybrid between natural and forced ventilation because they use buoyancy forces of the more congested warm air as the driving force of air transport in rooms. The following points should be given due consideration when designing improved ventilation systems:

### System design

- restrict design ratings to base requirement (windows for peak load)
- supply air inlets at rooms bottom (out of occupational zone)
- large cross section of inlets for low air velocity
- supply air temperature below average room temperature
- exhaust-only systems too require properly located supply air inlets
- exhaust air inlets at ceiling of rooms and close to contamination source
- use air ducts with low hydraulic losses (noise, power)
- filters required for every air intake
- compatibility heating/ventilation system to be evaluated
- acceptance test for every installation

### Equipment Design

- efficiency of ventilators/motors unsatisfactory
- system should work properly without attendance
- offer manual interference **option** (acceptance !)
- warning light for filter contamination
- filter cleaning procedure to accomodate user
- complete moduls for safe and low cost installation
- units for retrofits required
- design for more cost effective production.

## Conclusions

Conventional ventilation methods based on infiltration and window opening cannot secure proper air quality, and at the same time provide energy conservation and user comfort.

No intelligent ventilation habits can be expected of the average user.

All ventilation systems investigated had more or less severe shortcomings.

Present ventilation systems for dwellings based on the principle of contamination dilution are rejected by many users because of inherent noise and draught effects.

"Soft" displacement ventilation techniques taking advantage of natural bouyancy forces are expected to provide major improvements in ventilation efficiency and user comfort.

Ventilation systems should not necessarily require regular attendance.

Systems on the market offer a lot of potential for functional improvement and more cost effectiveness regarding production and installation.

The retrofit sector is neglected.

Acceptance tests should be compulsory.

Future times may probably consider ventilation systems for the cool climates as natural a thing as central heating.

## References


1. Daler R., Hirsch E., Haberda F., Knöbel U., Krüger W.
   Bestandsaufnahme von Einrichtungen zur freien Lüftung im Wohnungsbau
   Forschungsbericht BMFT-FB-T84-028, Friedrichshafen 1984

2. Haberda F., Meyringer V., Trepte L.
   Bestandsaufnahme zur Ausführung von Lüftungsanlagen im Wohnungsbau
   Forschungsbericht BMFT, Friedrichshafen 1985 (to be published)

3. Meyringer V.
   Voraussetzungen für den wirtschaftlich sinnvollen Einsatz von Lüftungsanlagen im Wohnungsbau
   Forschungsbericht BMFT, Friedrichshafen 1984 (to be published)

4. International Energy Agency
   Final Report Phase 1 Annex IX "Minimum Ventilation Rates"
   Uhldingen-Mühlhofen 1984

5. Flatheim G.
   Air Conditioning without Draft and Noise
   Proc. Indoor Air, Stockholm 1984

6. Sandberg M., Sjöberg M.
   A Comparative Study of the performance of General Ventilation Systems in Evacuating Contaminants
   Proc. Indoor Air, Stockholm 1984

7. Skaret E.
   Contaminant Removal Performance in Terms of Ventilation Effectiveness
   Proc. Indoor Air, Stockholm 1984





## Summary

V. Meyringer: Ventilation Systems in Residential Buildings - Requirements to the design of Systems and Equipment. The paper evaluates outcomes of the investigation programm "Ventilation in Residential Buildings" sponsored by the German Federal Ministry for Research and Technology. Its intention is to point out shortcomings of the present ventilation scene, to compile basic requirements for more efficient systems and to present some solution proposals. The issue includes the aspect of users behaviour, which is felt to have been neglected so far. It was found that conventional ventilation methods based on infiltration and window opening cannot secure proper air quality, and at the same time provide energy conservation and user comfort, nor can intelligent ventilation habits be expected of the average user, for subjective and for objective reasons. All ventilation systems investigated had more or less severe shortcomings, which were responsible to a great deal for the low acceptance observed. "Soft" displacement ventilation techniques taking advantage of natural bouyancy forces instead of contamination dilution can be expected to provide major improvements in ventilation efficiency and user comfort in the future. Design and construction of ventilation systems presently in use offer not only plenty of opportunity for functional improvement and for more cost effective production and installation, but rather must this improvement be considered a prerequisite for more market penetration.

## Kurzfassung

V. Meyringer: Lüftungssysteme für Wohnungen - Anforderungen an Planung und Ausführung. Der Beitrag wertet Ergebnisse des Forschungsprogammes "Lüftung im Wohnungsbau" aus. Das Programm wurde vom Bundesministerium für Forschung und Technologie finanziert. Es werden Mängel heute üblicher Lüftungssysteme aufgezeigt, Anforderungen an verbesserte Systeme definiert und einige Lösungsansätze aufgezeigt. Die Betrachtungen schließen den bisher vernachlässigten Aspekt "Benutzerverhalten" ein. Die wichtigsten Ergebnisse: Es ist nicht möglich, durch Fensterlüftung gleichzeitig die Forderungen nach Energieersparnis und ausreichender Raumluftqualität sicherzustellen. Aus subjektiven wie aus objektiven Gründen erscheint es unrealistisch, vom durchschnittlichen Nutzer sinnvolles Lüftungsverhalten zu erwarten. Alle untersuchten Lüftungsanlagen wiesen mehr oder weniger schwerwiegende Mängel auf, die auch zu Akzeptanzproblemen führten. Lüftungsstrategien, die die natürliche Schichtung der Raumluft nutzen ("Soft-Systeme") lassen erhebliche Verbesserungen an Effizienz und Komfort erwarten. Funktionelle Verbesserungen und Preisreduktionen durch kostengünstigere Herstellung und Montage ercheinen als Voraussetzung für eine die weitere Verbreitung am Markt.

## Sommaire

V. Meyringer: Systèmes de ventilation pour habitations - exigences relatives au planning et a la realisation. Le présent article évalue les résultats du programme de recherche "La ventilation dans la construction d'habitations", programme finance par le Ministere Fédéral de Recherche et de Technologie de la R.F.A. Il a pour but de déterminer les défauts des systèmes de ventilation actuellement en utilisation, de définir les exigences quant à des systèmes modifiés et de formuler quelques propositions de solutions. Le programme tient compte d'un aspect qui a été peu considéré jusqu'à présent: le comportement de l'utilisateur. Les résultats principaux de l'étude montrent qu'il n'est pas possible d'assurer simultanément, à l'aide de la ventilation par la fenêtre, les exigences d'une économie d'énergie et d'une qualité satisfaisante de l'air intérieur. Il parait irréaliste d'attendre de l'utilisateur moyen un comportement de ventilation raisonnable. Toutes les installations de ventilation ayant fait l'objet de l'étude montraient des défauts plus ou moins graves qui causaient même des problèmes d'acceptance. Les stratégies de ventilation profitant des couches naturelles de l'air intérieur (soft systems) laissent espérer des améliorations importantes du point de vue de l'effcacité et du confort. Des modifications fonctionnelles et des réductions des prix moyennant une fabrication et un montage plus économiques paraissent préliminaires pour une propagation plus étendue sur le marché.