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AIR HEATING SYSTEMS IN AIRTIGHT MULTIFAMILY RESIDENTIAL BUILDINGS

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1. Synopsis

This paper presents an analysis of indoor climate in buildings with forced air heating systems. The results is based on indoor climate measurements and extensive interviews with the occupants. The analysis shows that design criteria is of great importance for the occupants conceptions of thermal comfort in buildings with air heating systems. Forced air heating systems could be a way to provide mechanical supply air with less problems with the thermal comfort, such as draught, than in ordinary supply- and exhaust air ventilation systems. Especially those designs that use overhead ventilators on the interior walls seems to give a good thermal comfort in the occupant zone. If floor ventilators under the windows are chosen, a very careful design has to be made of both the ventilators and adjacent building details. Special attention has to be put into the coordination between designers and builders.

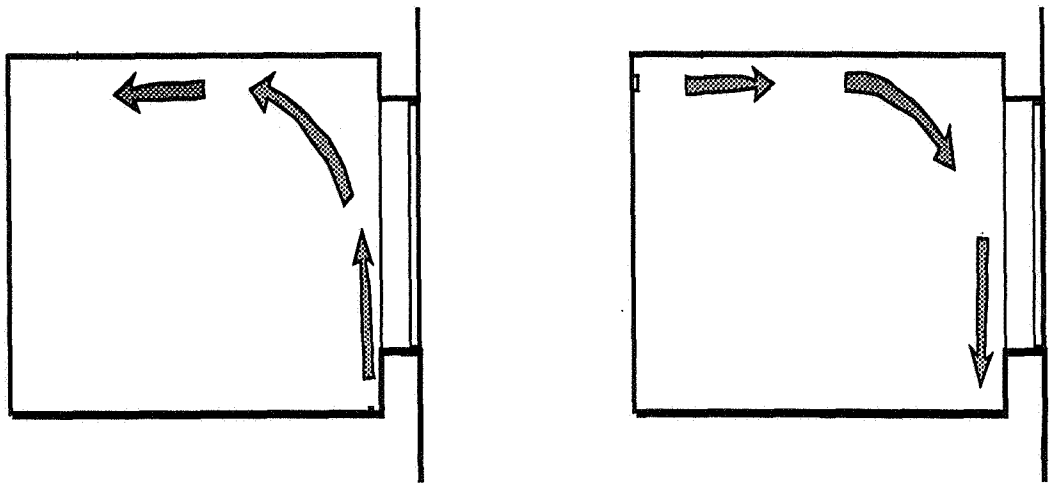
2. Introduction and purpose

The "Stockholm Project" (1) is a large joint experimental research and demonstration project for evaluation of new energy saving technology in buildings. Primarily established products are used, but in each of the six buildings one or more new methods of energy conservation is tested. The energy demand for heating is considerably lower in these buildings compared to a larger group of buildings of similar types, built during the same time period in Stockholm. All the buildings are airtight and well insulated, some of them better than the Swedish Building Code requirement.

In the Stockholm Project three heating and ventilation system types are represented.

- forced air heating + supply- and exhaust air with heat exchangers (SE).
- hydronic heating + supply- and exhaust air with heat exchangers (SE).
- hydronic heating + exhaust air (E).

In this paper the presentation is limited to a comparison between buildings with forced air heating systems + SE-systems and buildings with hydronic heating + SE-systems.



Exterior wall supply **Interior wall supply**

Fig. 1. The two methods of air distribution in the Kejsaren Building, exterior- and interior wall supply

Two different methods of air distribution are being tested and evaluated in the air heated buildings (Fig.1.):

1: Exterior wall supply via floor level ventilators under exterior perimeter windows (the Kejsaren Building).

2: Interior wall supply from overhead ventilators on interior walls, thereby providing no direct downdraught protection beneath exterior perimeter windows (the Höstvetet Building).

The aim of this study was to:

1: Compare different heating and ventilation systems from the occupants point of view, using sociological interviews.

2: Study the thermal comfort in the apartments with air heating systems, using detailed measurements of air movements and temperatures.

3: Give advise on further research, development and improvements of the heating and ventilation systems.

The ventilation systems are similar for both buildings with a central mechanical ventilation system combined with air-to-air heat exchanger. Each apartment has an air heating unit in which the incoming ventilation

air supply, at a rate of 0.5 air changes per hour, is mixed with recirculated air from the apartment to provide a total air flow rate equivalent to 1.3 (Kejsaren Building) to 2.5 (Höstvetet Building) air changes per hour respectively.

The two buildings have a very good thermal insulation and air tightness. A very low air circulation rate is thus required to provide the necessary heating load. In the Kejsaren Building the maximum supply air temperature is +45 °C and in Höstvetet Building +35 °C.

Interviews has been done in all buildings in the Stockholm Project. To get a reference the data was supplemented with interviews from an ordinary building built during the same time.

The analysis is based on answers from:

- forced air heating + (SE) in 63 apartments
- hydronic heating + (SE) in 136 apartments
- hydronic heating + (E) in 88 apartments

The parameters studied in this paper are the occupants answer on how they classify their indoor thermal climate, if they have any possibility to achieve thermal comfort, how they classify the air quality.

3. Technical description of the two buildings

3.1 The Kejsaren Building

The ten apartments in the Kejsaren building (2) are being heated by forced warm air supplied by an air heating system. Each apartment has its own separate air heating unit, in which the incoming ventilation, at a rate of 0.5 air changes per hour, is mixed with filtered recirculated air from the apartment to provide a total air flow rate equivalent to 1.3 air changes per hour. The air temperature is controlled by thermostats to balance each apartments transmission losses.

In five of the apartments, air is distributed from the exterior walls at floor level beneath the windows. A simpler system is being tested in the other five apartments, where air is being supplied from ventilators placed the interior walls of the rooms, which means that there is no direct protection against cold downdraught, such as radiators beneath the windows.

3.2 The Höstvetet Building

The 71 apartments in the Höstvetet Building (3) are being heated by a forced warm air heating system similar to the exterior wall supply system in the Kejsaren building. Each apartment has also in this building its own separate air heating unit. The supply air, at a rate of 0.5 air changes per hour, is mixed with filtered recirculated air from the apartments to provide a total air flow rate up to 2.5 air changes per hour depending on the heating load. The heat for the unit is supplied by the domestic hot water circuit, which in this building serves two purposes.

4. Evaluation methods

4.1 Interviews

Personal interviews has been done in all of the Stockholm Project Buildings to gather information from the occupants. One person from each household was chosen. Almost all households has participated in the interviews, which were made one year after the occupants moved into their apartments.

The occupants experience of the indoor climate was studied from many angels. The first questions was related to general aspects on heating and ventilation, air quality, noise etc. Each subject was then studied more deeply with more specific questions, related to the technical systems and time of the year.

The heating was studied by questions of wanted indoor temperature, even or uneven temperature, if the apartment temperature was regarded too hot or too cold and if the occupants regarded the floor temperature hot or cold.

The ventilation in the apartments was studied by questions on the ventilation in general, draught problem, air quality and bad odour problem.

The indoor climate and thermal comfort was then evaluated from the questions of both heating and ventilation. The occupants also had the opportunity to express if they had had any possibilities to achieve thermal comfort. In the indoor climate section questions of general character was also used, such as health problems and the their relation to the apartment.

In the analysis of the indoor climate the occupants experiences was related to different household data, to the building design, and to the heating- and ventilation systems. The result was then compared to measurement data from technical evaluation.

4.2 Thermal comfort measurements in the apartments

The Buildings of the "Stockholm project has each been monitored (4) continuously in more than two years. Data based on five minutes intervals is recorded as hourly mean values in a database. Indoor temperatures are recorded in approximately five of the apartments.

Using that data a comprehensive study was made (5). To further study the air heating systems an intensive study was made during two days in February 1988, as a part of the indoor climate evaluation in the Stockholm Project (6). The weather was cloudy during these two days, and the outdoor temperatures were -1 - -3 °C..

The parameters studied in this paper were:

Air speed close to the ventilators
Air speed in the room
Air direction
Supply air temperatures
Indoor air temperature

The measurements were made accordingly to ISO 7726 (7).

5. Results

The results presents the indoor climate experiences of the occupants in relation to the ventilation system used in the building. It also presents the measurements of air velocities in some selected apartments in the two buildings. The data from measurements are then compared to the experiences of the idoor climate in the selected apartments.

5.1 Experiences of indoor climate - Interviews

5.1.1 Ventilation

Slightly more than half of the occupants answers that they consider the ventilation of the apartments as good (Fig. 2.), but there are also many who are dissatisfied, especially with the ES-systems.The highest percentage of satisfied occupants are found in the buildings with E-systems.

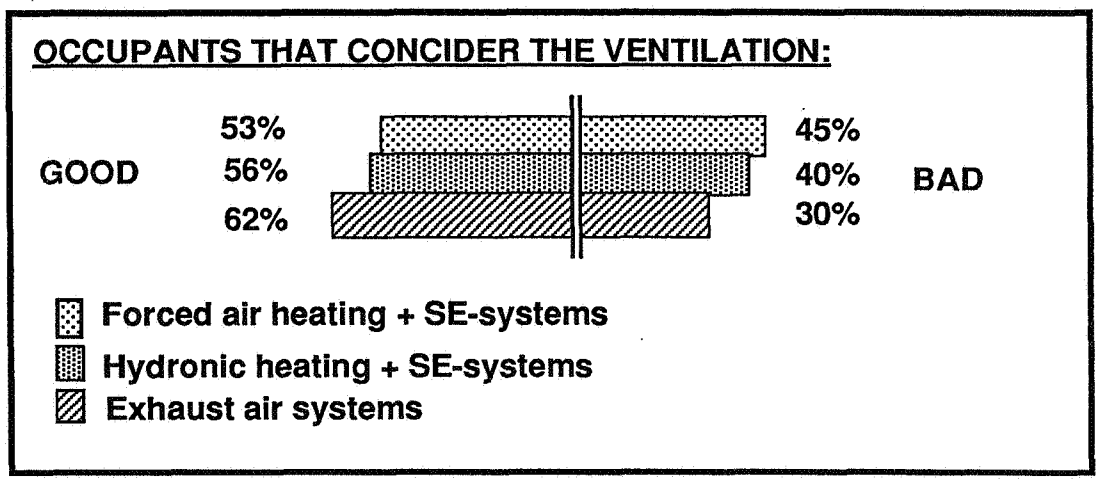


Fig. 2. The occupants general experience of the ventilation system during the winter. Occupants who answers that the ventilation is either good or bad are not represented in the figure.

5.1.2 Noise from the ventilation system

As a result of the improved insulation technology used today in Sweden, the noise from the outside of the buildings has decreased, and one of the consequences is that the occupants pay more attention to indoor noises. Especially in buildings with SE-systems combined with radiators the occupants are disturbed by noises from the ventilation system. In those buildings 47% of the occupants are disturbed (Fig 3.).

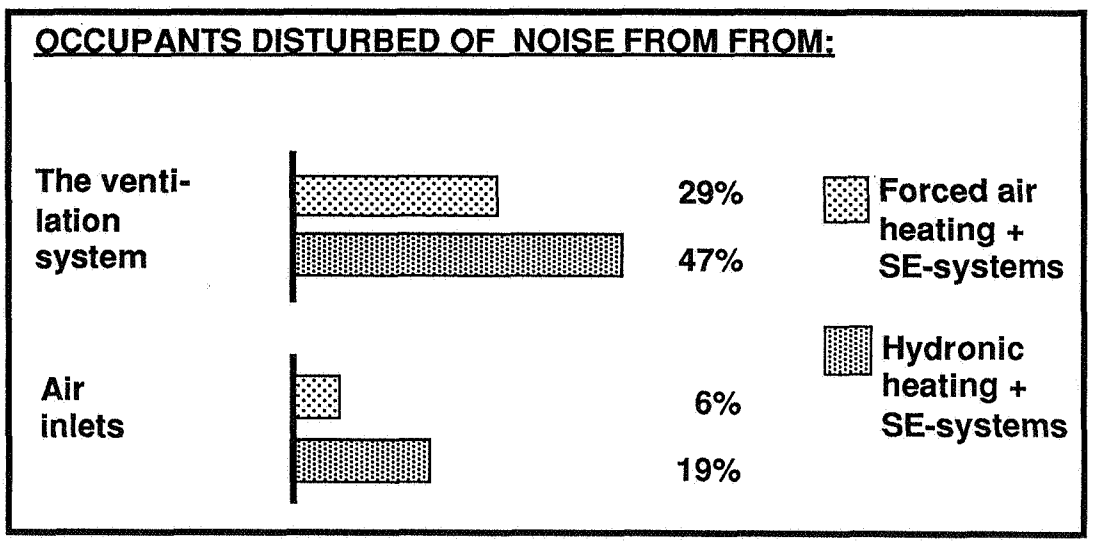


Fig. 3. The occupants experience of noise from the ventilation system.

5.1.3. Air quality

The air quality was described by the occupants with a series of descriptive words (Fig. 4.).

When studying the answers on air quality the occupants in buildings with air heating systems complains more about dusty and stagnant air than those living in buildings with supply- and exhaust ventilation systems. There are also less occupants in these buildings that regard the air free of odours. Even at the question of how the occupants regard the air quality as a whole, air heating systems got the lowest ranking. This indicates that there are other factors that affects the answers, as for example the occupants uncertainty of the air heating systems function and that they find the systems hard to control. Questions as: What kind of air is coming into the apartment?, Is it exhaust- or supply air?, Do I get enough fresh air or do I have to open a window?, are frequent.

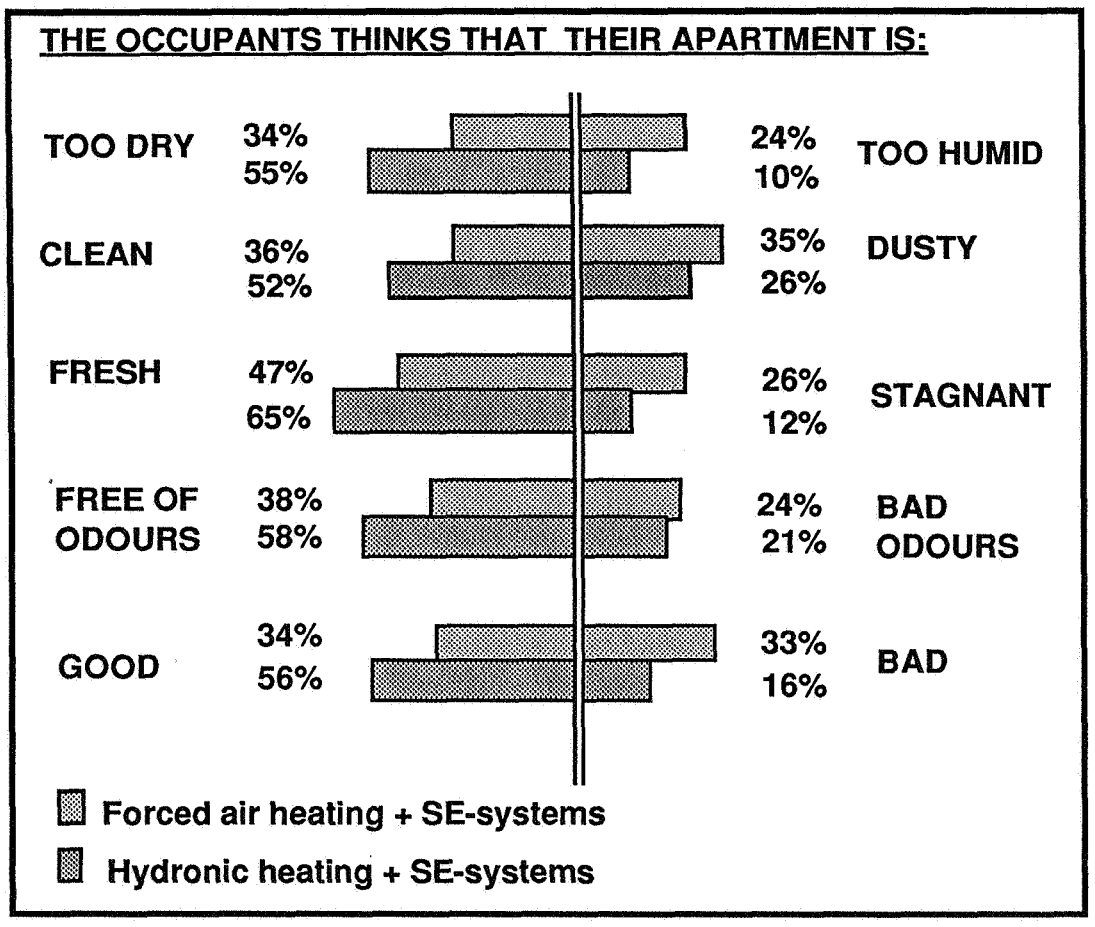


Fig. 4. The occupants experience of the air quality in the apartment during the winter. Occupants who answers that the ventilation is either good or bad are not represented in the figure.

5.1.4. Indoor temperature

In all of the buildings, the occupants consider it to be too cold in their apartments (Fig. 5.). 51% of the occupants in apartments with air heating systems and 63% of the occupants in building with supply- and exhaust air ventilation systems find the temperature is too cold during the winter. In the apartments with air heating systems there is also a group of occupants who considers the indoor temperature too warm. This could be a result of the difficulties to control the temperature in the different rooms in the apartments. On the question on the most negative aspect on forced air heating, the occupant often specificly express dissatisfaction with the indoor air temperature adjustment possibilities.

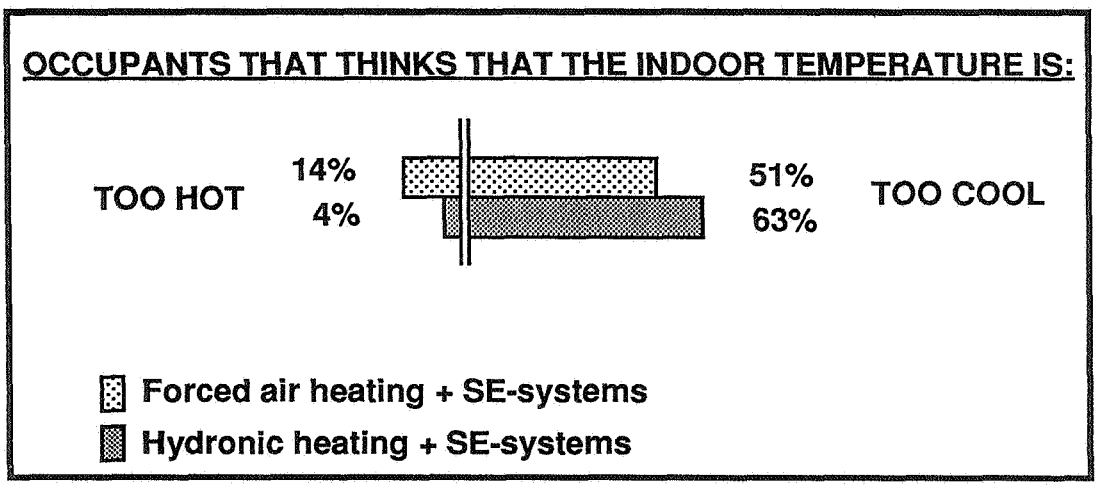


Fig. 5. The occupants experience of the indoor temperature in the apartment during the winter. Occupants who answers that the ventilation is either good or badare not represented in the figure.

5.1.5 Draught

The experience of draught in the apartment is closely related to the experience of the indoor temperature, which is a possible explanation of the differences in the answers from the two air distribution systems (Fig. 6.). The survey shows that in building with supply- and exhaust air ventilation systems and hydronic heating systems there are a higher number of occupants who feels draught than in buildings with forced air heating systems. Explanations of this could be high air velocities in combination with lower temperatures and / or badly designed ventilators.

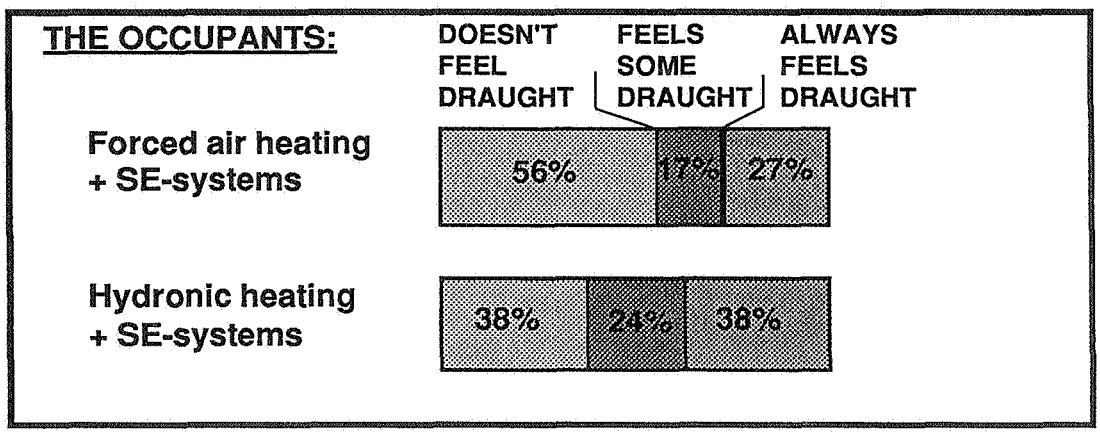


Fig. 6. The occupants experience of the draught in the apartment during the winter.

5.2. Thermal comfort in the Kejsaren Building, interviews - measurements

In five of the apartments in Kejsaren the occupants have expressed that the temperature is too cold during the winter. The most noticeable difference between the two air distribution systems are that there are more complains of draught and cold floors (Fig. 7) in the apartments with air ventilators at floor level beneath the windows.

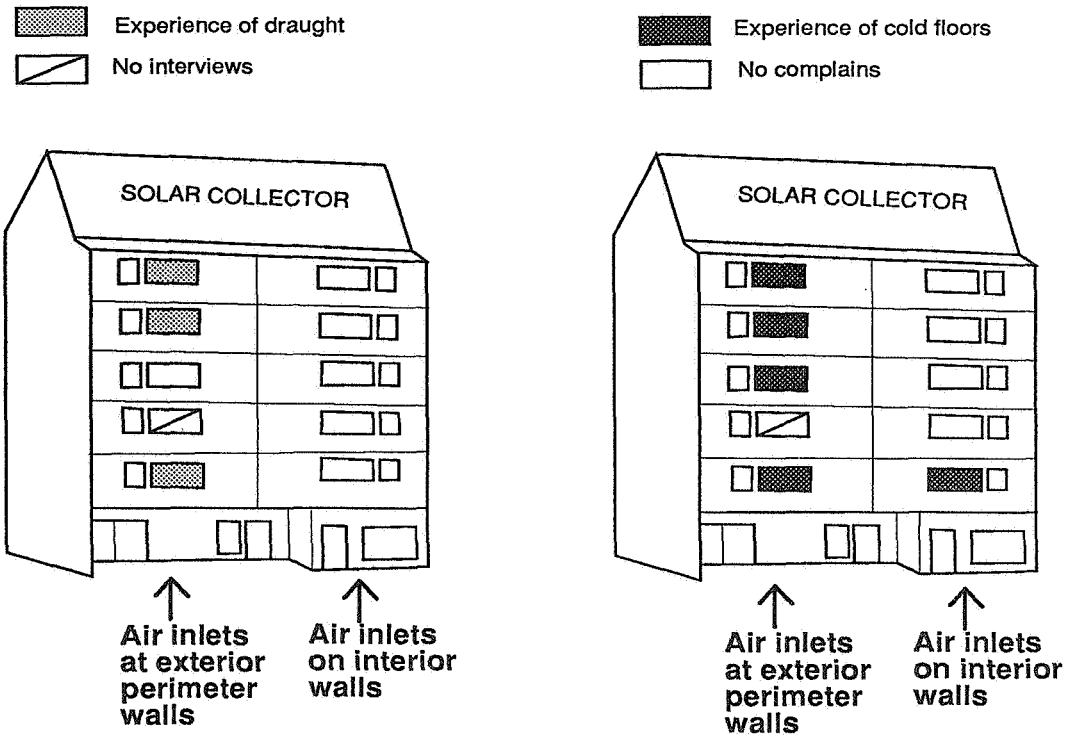


Fig. 7. The occupants experience of draugt and cold floors in the Kejsaren apartments during the winter.

5.2.1 Floor level ventilators under the windows, Kejsaren

Air movement pattern in the living room and in a bedroom with ventilators placed in the floor, close to the exterior wall (Apartment A) are shown in Fig. 8 and Fig. 9. A small obstacle forces the air into an unwanted direction. Here a small protruding edge of the window-sill (approximately 8 mm) causes draught problems in the occupant zone close to the windows.

Even though the air temperature is rather high the tenant in this apartment feels that it is too cold during the winter. This is also true for different rooms in the apartment. During the winter there are problems with draught in both bedrooms and living-room, especially from the air ventilators, balcony door and windows up to a level of approximately 2 meters. This corresponds well with the measurements of air movements. No special consideration has been taken to the ventilator in the furnishing of the apartment to awoid the feeling of draught.

In another apartment (B) experiments were made to improve the design (Fig. 10.). A lid with channels that should direct the air flow in the right direction was mounted over the ventilators. Howewer, the pressure drop through those channels then became too high and a air stream was forced out along the floor, wich affects the feeling of cold draught and cool floors.

No cold downdraught could be detected at the windows.

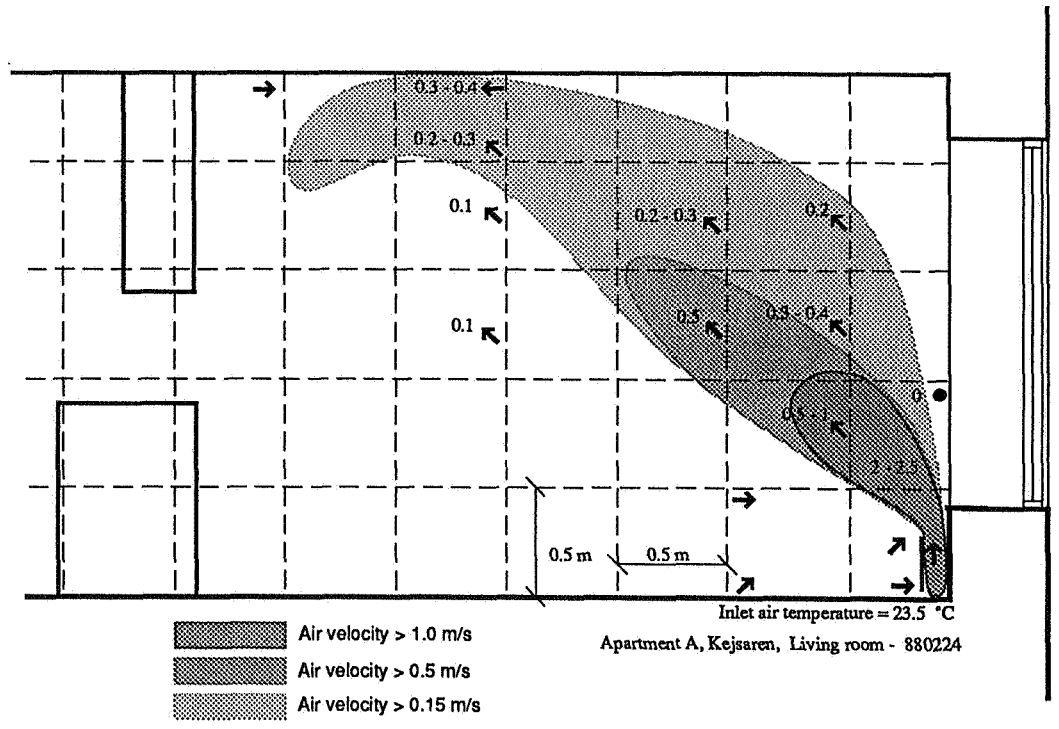


Fig. 8. Section through a sittingroom with exterior wall supply, apartment A, Kejsaren.

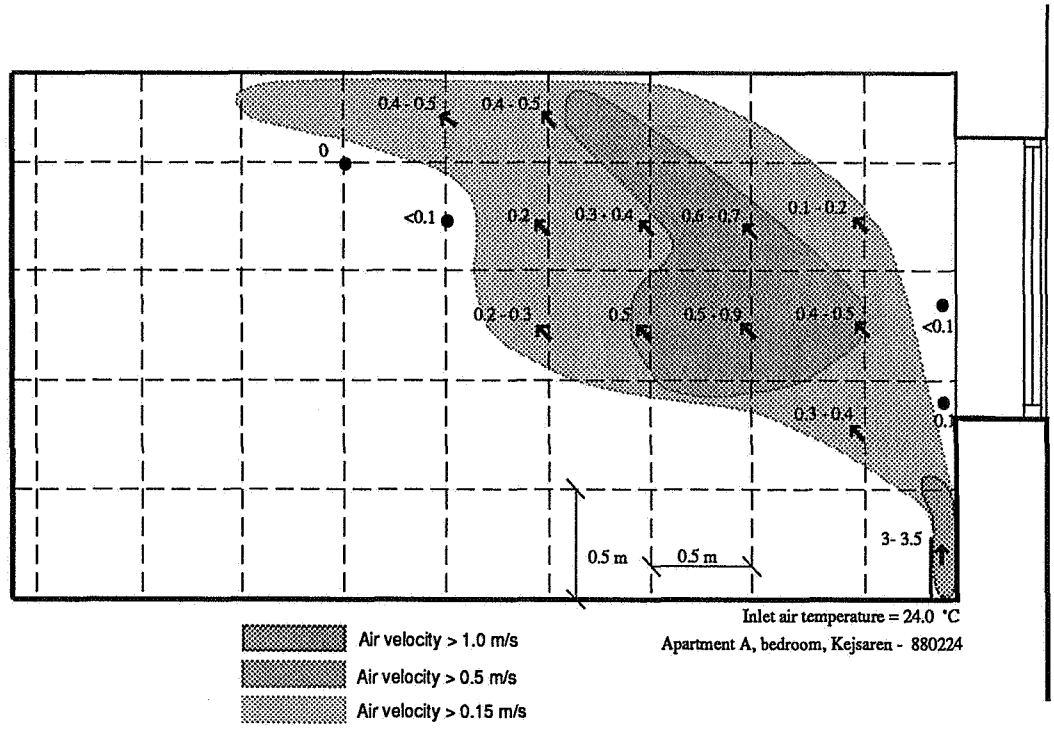


Fig. 9. Section through a bedroom with exterior wall supply, apartment A, Kejsaren.

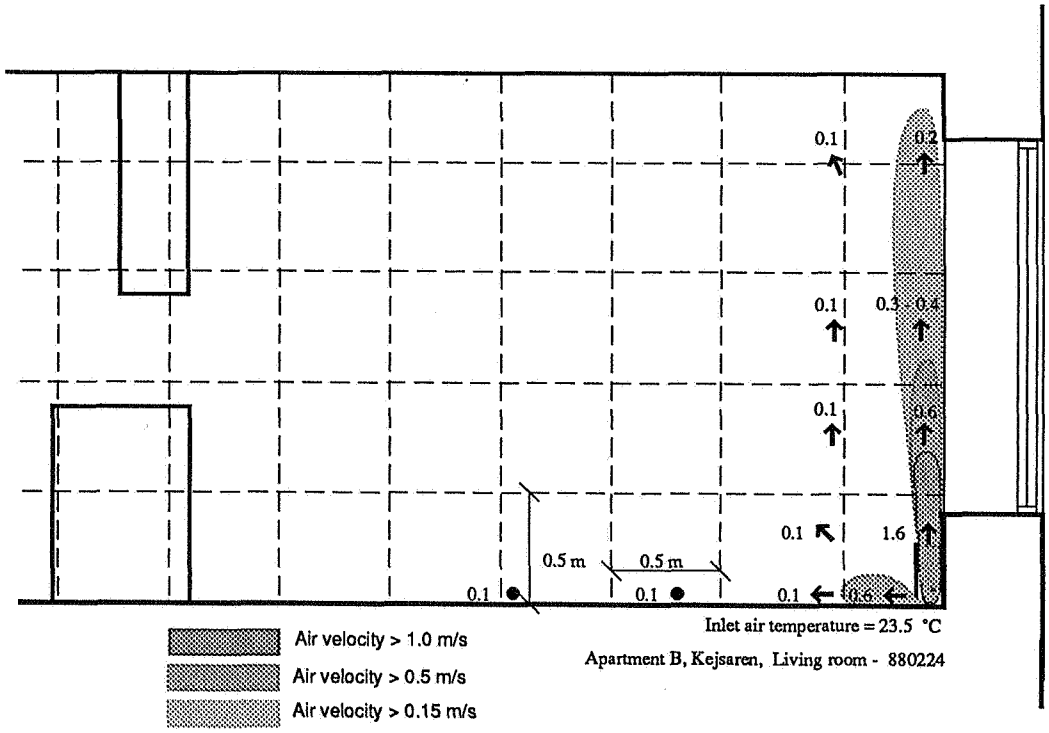


Fig. 10. Section through a sittingroom with exterior wall supply, apartment B, Kejsaren.

5.2.2 Overhead ventilators on interior walls, Kejsaren

The method to distribute the air through overhead ventilators on interior walls close to the ceiling gives an even air flow under the roof and small influence on the occupant zone. The air flows out as a thin layer close to the ceiling and all the air movement is reduced to this zone.

Apartment C, (Fig. 11.): In this apartment situated at the first floor, the occupant express that the indoor air temperatureis too cold during the winter and too warm during the summer. They use clothing to try to achieve thermal comfort during the winter, but only succeed to do that in the bedrooms. In this apartment no discomfort related to draught has been perceived. No special consideration was taken to the ventilators when the apartment was furnished.

No cold downdraught could be noticed close to the windows, exept for air movement at the edge of the window-sill. That air stream dissolved fast and no significant draught problems could be detected in the occupant zone.

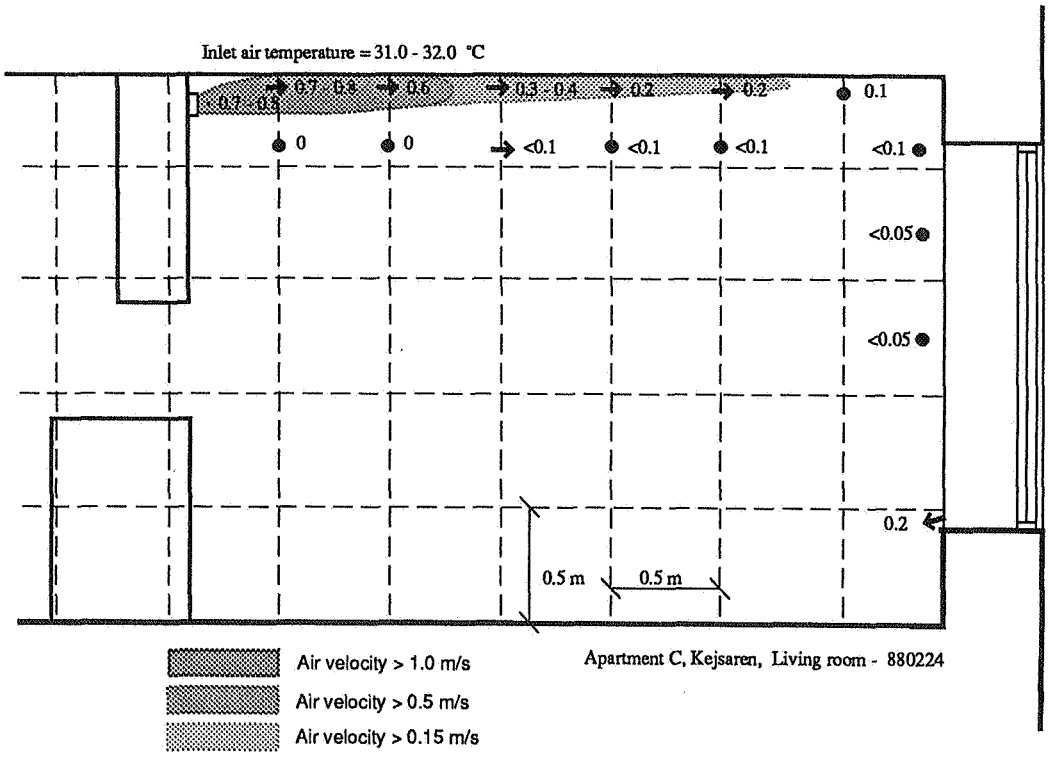


Fig. 11. Section through a sittingroom with interior wall supply, apartment C, Kejsaren.

Apartment D (Fig. 12.): In this apartment the occupants express thermal comfort satisfaction during both winter and summer, in both bedrooms and living-room.

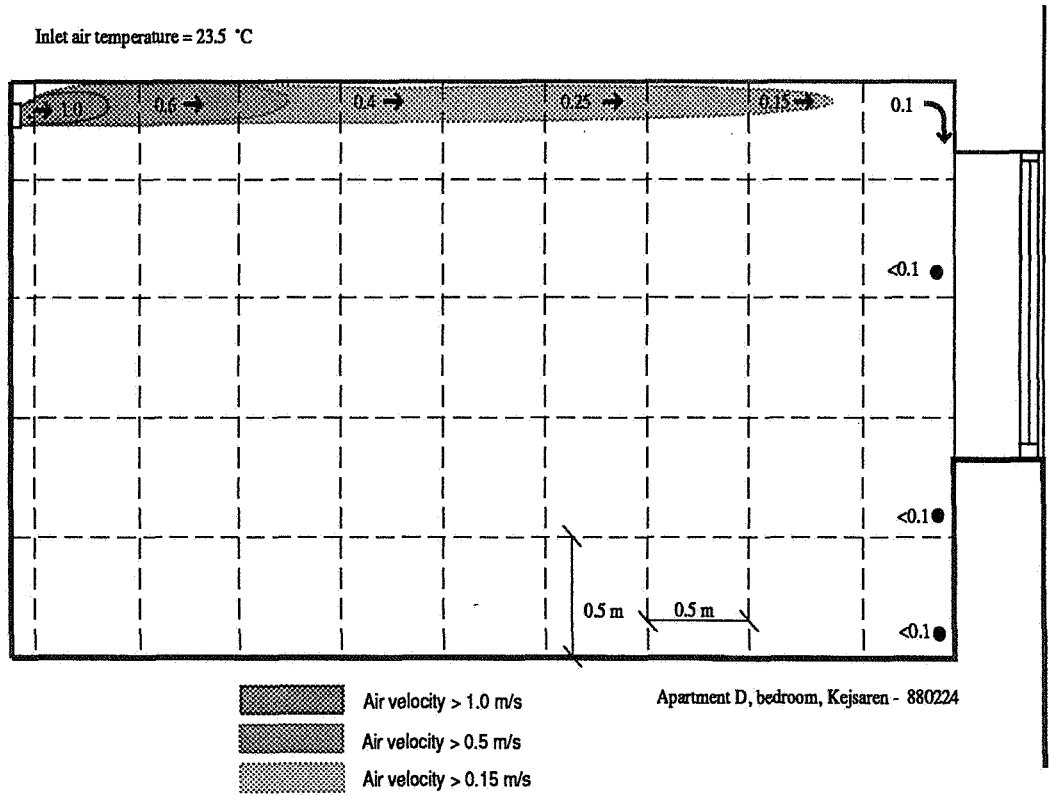


Fig. 12. Section through a sittingroom with interior wall supply, apartment D, Kejsaren.

5.3. Thermal comfort in the Höstvetet Building, interviews - measurements

This building has a window-sill which forces the air into the occupant zone (Fig. 13.). Even here small obstacles forces the air to turn into the room (Fig 14.). Compared with the supply air in the Kejsaren Building (Fig.8.), the influences on the air movements are much smaller.

The occupant in this apartment express satisfaction with the indoor temperature during the winter but complains about too high indoor air temperatures during the summer. The occupant doesn't neither express any complains of draught, even if the figure shows that there are high air velocities in the occupied zone. This could be due to the fact that the occupant has adjusted the furnitures after the placement of the ventilators.

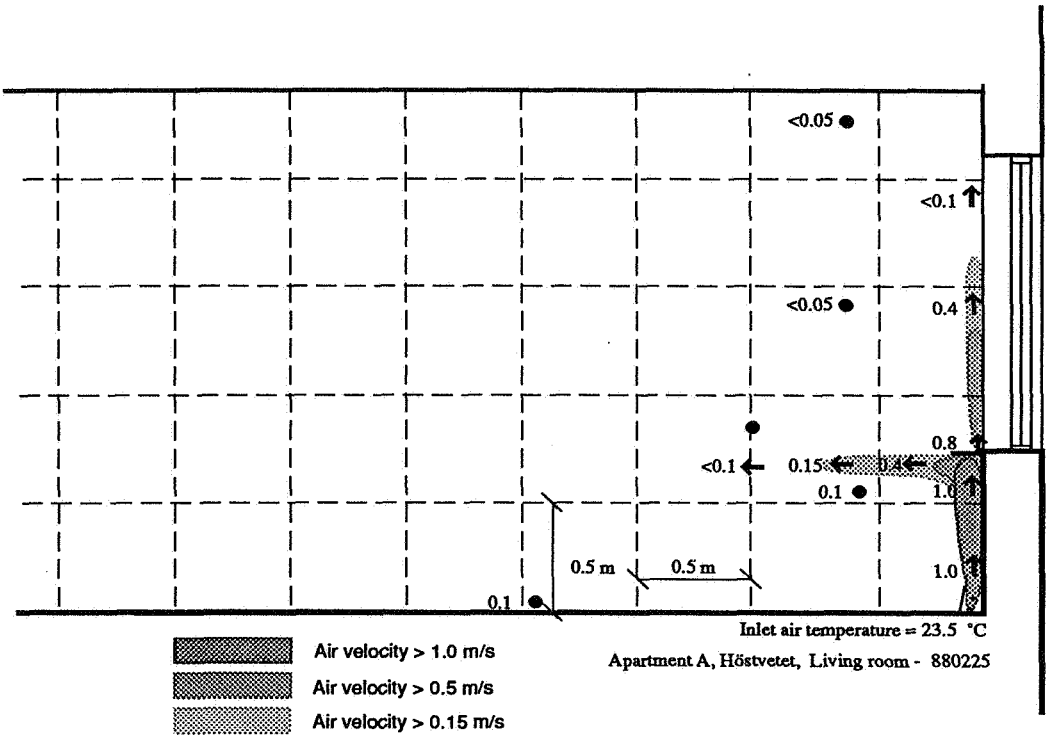


Fig. 13. Section through a sittingroom with exterior wall supply, Höstvetet.

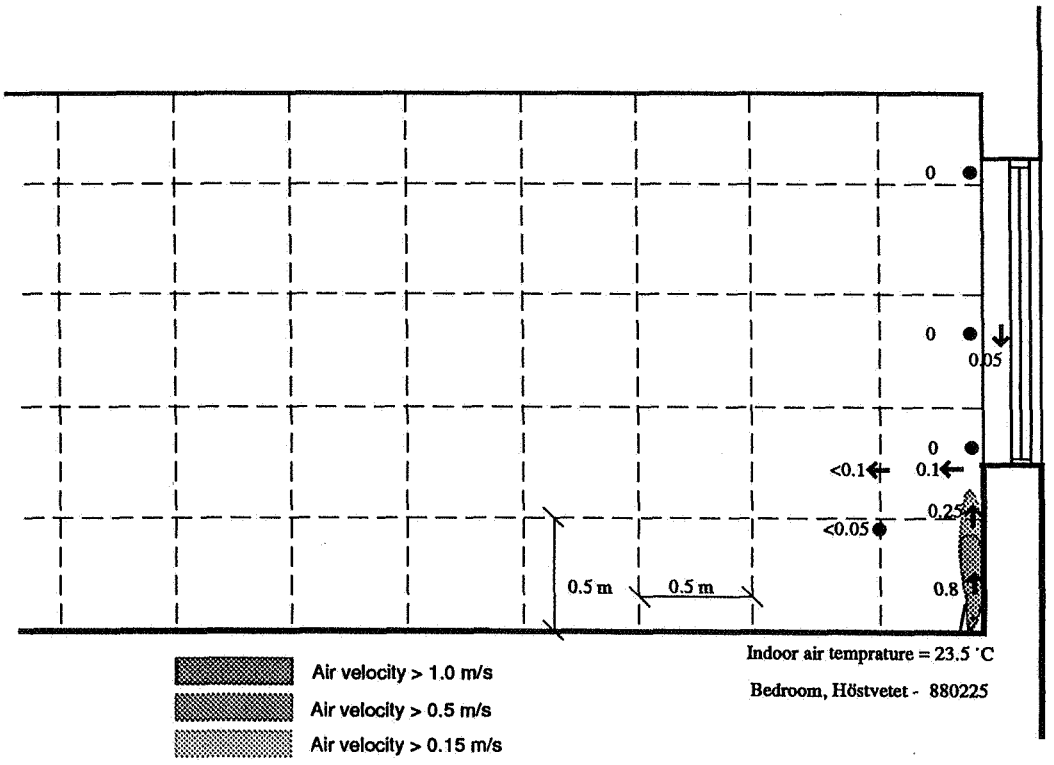


Fig. 14. Section through a bedroom with exterior wall supply, Höstvetet.

6. Discussion

In Sweden, there is a lively discussion about mechanical ventilation system in energy efficient and airtight buildings today. It is well known today that many factors affects the indoor climate. Not only the heating ventilation system but also building materials, thermal cold bridges, tightness and other building design criteria is of great importance. Healthy buildings with installations that provide good air quality without any inconvenience for the occupants, such as for example noise problems, is requested. A broad approach is thus important, not only when evaluating indoor climate, but also when evaluating the building design, the heating and ventilation systems, the indoor air quality and the occupants experience and use of the building. The occupants often express a general feeling of uncertainty when exposed to new mechanical ventilation systems, such as forced air heating. Better possibilities for individual adjustment of the indoor temperature and a better air quality is required.

This study indicates that air heating systems could be a way to provide mechanical supply air with less draught and with less thermal comfort problems than in ordinary supply- and exhaust air ventilation systems. Especially those designs that use overhead ventilators on the interior walls seems to give a good thermal comfort in the occupant zone.

If floor ventilators under the windows are chosen a very careful design has to be made of both ventilators and to the details in their surroundings. Special attention has to be put into the coordination between designers and builders.

7. Recommendations

Forced air heating system has the advantage that there are less complains about draught, but it has a disadvantage in that the occupants doesn't consider the air quality to be as good as with the other systems. Here the technology should be improved by:

Design the ventilation systems for better air quality. Ventilation systems that cause an unhealthy indoor climate in the apartment must be awoided.

Design the ventilators for better performances of both draught and noise.

Design systems for individual adjustment possibilities in the apartments

Give the tenants good information if there are individual adjustment possibilities in the apartments.

Develop methods to measure and display ventilation- and air quality data in each apartment.

8. References

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