The Role of Ventilation
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# Improvement of Domestic Ventilation Systems

J Heikkinen, M-L Pallari

VTT Building Technology Indoor Environment and
Systems, P O Box 1804, FIN 02044 VTT Finland

## SYNOPSIS

The aim of the study was to identify methods for the renovation of ventilation systems in domestic buildings which are 3 - 8 storeys high. Three typical buildings were selected and the problems in ventilation were examined. The designers made their proposals for repairs and the research team analyzed the solutions and made improvements. The special problems compared with new buildings included less airtight building envelopes and leakages in existing ventilation ducts.

An analysis was performed, using a multi-zone airflow model, for the whole year and therefore the ventilation heat loss could be found in each case. As anticipated, the airflow rate of passive stack ventilation was too high in winter and too low in summer, but the system can be improved by means of controlled air inlets and outlets. A mechanical extraction system can be improved with demand-controlled ventilation instead of time control. The installation of heat recovery system requires improved sealing of the building envelope to minimize cross ventilation. The proposed systems will be tested and followed up later in experimental buildings.

## 1. INTRODUCTION

The renovation of existing high-rise residential buildings is becoming a major part of the construction work in Finland. At the same time the reduction of energy consumption is required to conserve the global environment. It has been estimated that 40% of residential heating energy is used for ventilation, which means that the renovation of ventilation systems may play a major role in decreasing the overall energy consumption in buildings.

There are two properties of the Finnish housing stock which have importance in the renovation of ventilation systems. Firstly, almost half (about 45%) of dwellings are in blocks of flats. Secondly, the buildings are fairly new: more than 70% of high-rise domestic buildings have been built since 1960. At that time mechanical ventilation was beginning to exceed natural ventilation in popularity.

The share of mechanical extraction ventilation in apartment blocks is currently more than 70%, leaving some 25% for natural ventilation. A typical mechanical system comprises an extractor fan on the roof of the building and a common vertical air duct shared by kitchens or bathrooms on all floors. The ductwork is much smaller and less expensive than in the natural ventilation system, where there is an individual extraction air duct from every kitchen and bathroom directly to the roof. The outdoor air usually enters through cracks in the windows or other components of the envelope. Purpose-built openings for incoming air, or air inlets, were taken into building practice since 1988 when the latest building code came into force. At the same time exhaust hoods in the kitchen became practically mandatory.

Most of the buildings built before 1980 already need repair or improvement. However, it is not known whether something should be done to the ventilation system at the same time. The main possibilities are to improve an existing passive stack ventilation system, change it for a mechanical extraction system, change it for a mechanical supply and extraction system, or to improve the existing mechanical extraction system. The improved systems should be more energy-efficient and they should satisfy the needs of the occupants: the kitchen ventilation should be better, airing should not be needed too often and draughts should be avoided.

The purpose of this project was to identify methods for the renovation of ventilation systems in domestic buildings which are 3 - 8 storeys high. Three typical buildings were selected and the problems in ventilation were examined. The designers made their proposals for repairs and the research team analyzed the solutions and made improvements.

## 2. COMPUTER SIMULATIONS

The analysis was performed mainly with using a multi zone airflow model Movecomp /2/, with which the building and the ventilation system could be described in detail. The computations were performed for a 4-storey building that currently has a passive stack ventilation system. The performance of the existing system, as well as possible improvements, were simulated.

The building has a basement and 3 inhabited floors. The length, width and height of the building are 75 m, 12 m and 14 m respectively. Most of the flats have only two walls facing the outside. Therefore, it was considered reasonable to compute only one 63 $m^2$ flat on each floor, as shown in figure 1. Each flat has three ventilation ducts of its own (flow area of each is about 280 $cm^2$) directly to the roof, but there are leakages between the ducts. The air leakages are set to measured values in the actual building, see table 1.

*Table 1. Air leakages of the investigated building.*

| Leakage route | Air leakage at 50 Pa |
|---|---|
| Outer walls | 105 L/s = 2.4 1/h |
| Apartment doors | 1 L/s |
| Floors between apartments | 19 L/s |
| Leakage between neighbouring air ducts | 24 L/s |
| Two air inlets | 50 L/s |

The building is located in urban surroundings where the wind speed at the building height is assumed to be 72% of the velocity at the weather station. Some additional computations were performed for city and flat surroundings where the relative wind speed is 52% and 105% respectively. These proportions are in close agreement with the values given by the British Standards Institution /4/. The building is assumed to be exposed to the wind. The pressure coefficients for the 12 wind directions were taken from reference /1/.

The simulations were performed for a total of 182 weather conditions. The annual results were obtained using the probability of each weather condition at Helsinki-Vantaa airport, Finland, over 30 years. The annual mean outdoor air temperature 4.4°C, mean wind velocity 3.9 m/s and the design temperature for heating installations -26°C give a general idea of the weather in Helsinki. In each ventilation case the extraction air change rate was adjusted to 0.5 air changes per hour at a temperature of 4.4°C and zero wind speed.

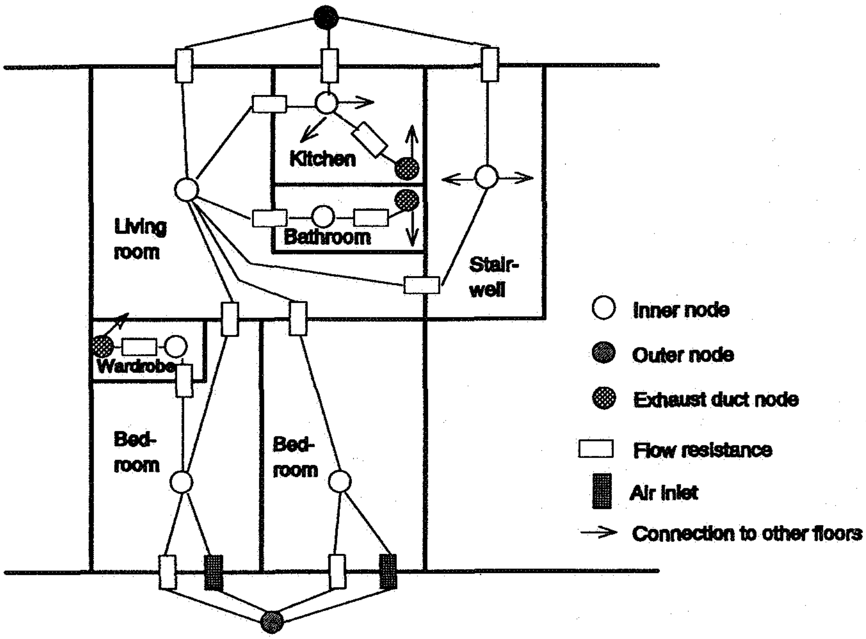



*Figure 1. The flow network of one of the four floors. The floors are connected by leakages in floors, leakages between extraction air ducts and the stairwell. The total number of pressure nodes is 75.*

## 3. NATURAL VENTILATION

The effect of control strategies for air inlets and outlets on the performance of natural ventilation is demonstrated in Figures 2, 3 and 4. Figure 2 shows the air change rates under different weather conditions. In Figure 3 the Helsinki weather is used to predict the annual stability of air change and, finally, Figure 4 shows the corresponding ventilation energies.

In the absence of wind the ventilation rate is lower than the target value of 0.5 1/h during warm weather and higher at cold weather. This is shown in Figures 2 and 3 where the upper left graph (no air inlets) represents the current situation in the building. It means that the occupants must increase ventilation during mild weather by opening windows. This will also correctly increase extraction airflow rates because the permeability of the building envelope controls the ventilation. The extraction air outlets are almost fully open and about 90% of the total available pressure difference is lost in the walls. During very cold weather the occupants should be able to control the air outlets to avoid excessive ventilation, draught and increased energy consumption (Figure 4). The need to regulate the extract air outlets is also especially important on lower floors and in more leaky buildings than this one.

The case with air inlets (upper right graphs in Figures 2 and 3) represents a situation in which the power to control the air change has been transferred to air outlets: they have 70% of the total pressure loss. The insensitivity to temperature variation is slightly better but the ventilation is much more wind-dependent because of cross ventilation. The high pressure loss in the extraction air terminals will diminish the risk of back flow through the extract air duct, which is a common problem during the winter months and a very difficult one to repair.

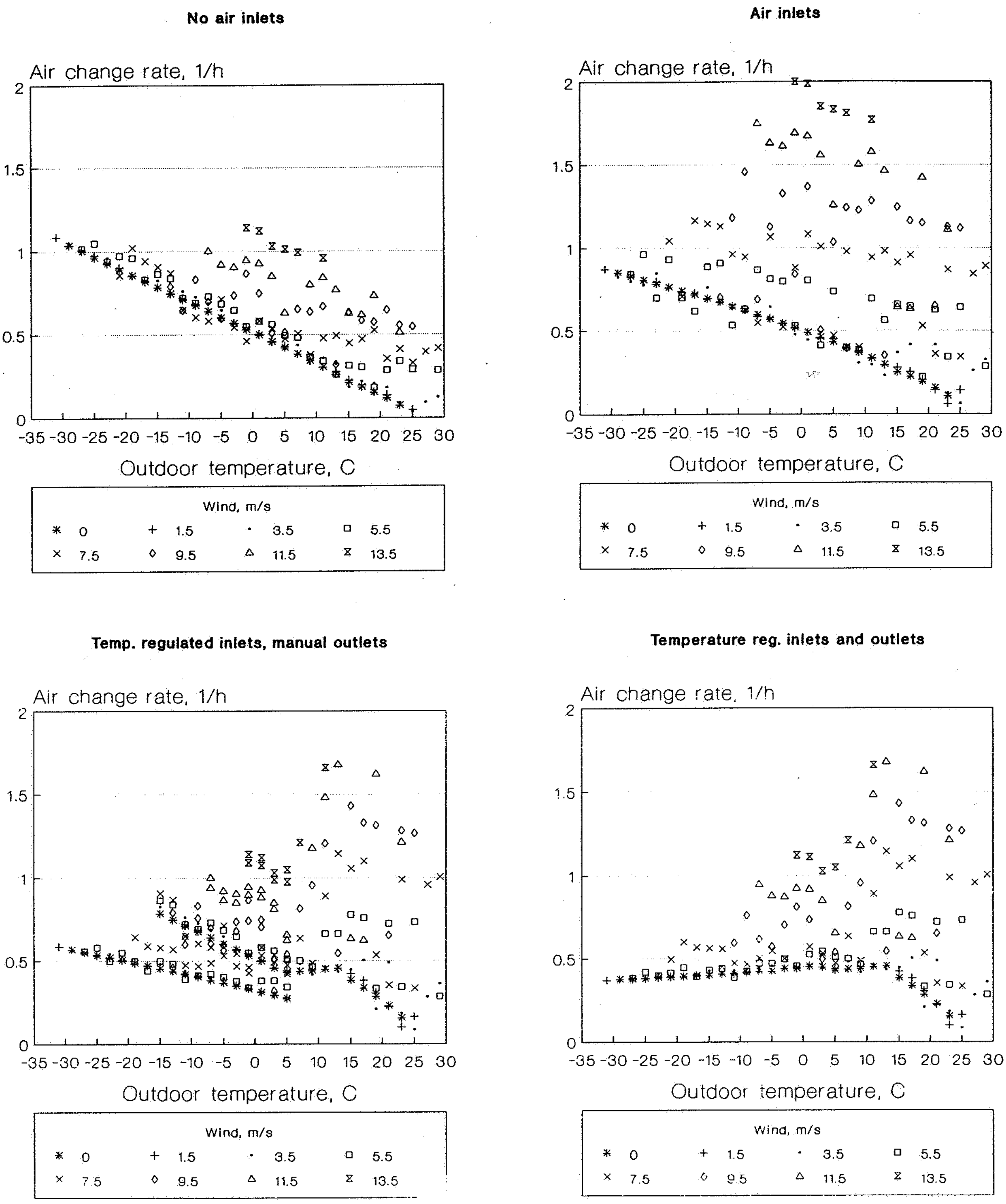



*Figure 2. Outdoor air change rate on the second floor of the three inhabited floors in a naturally ventilated building in different weather conditions. The four cases represent different control strategies for air inlets and outlets. The extract airflow rate is adjusted to 0.5 1/h in each case at 4.4°C and zero wind velocity. The wind velocity at the height of the building is 72% of the indicated velocity at the weather station.*

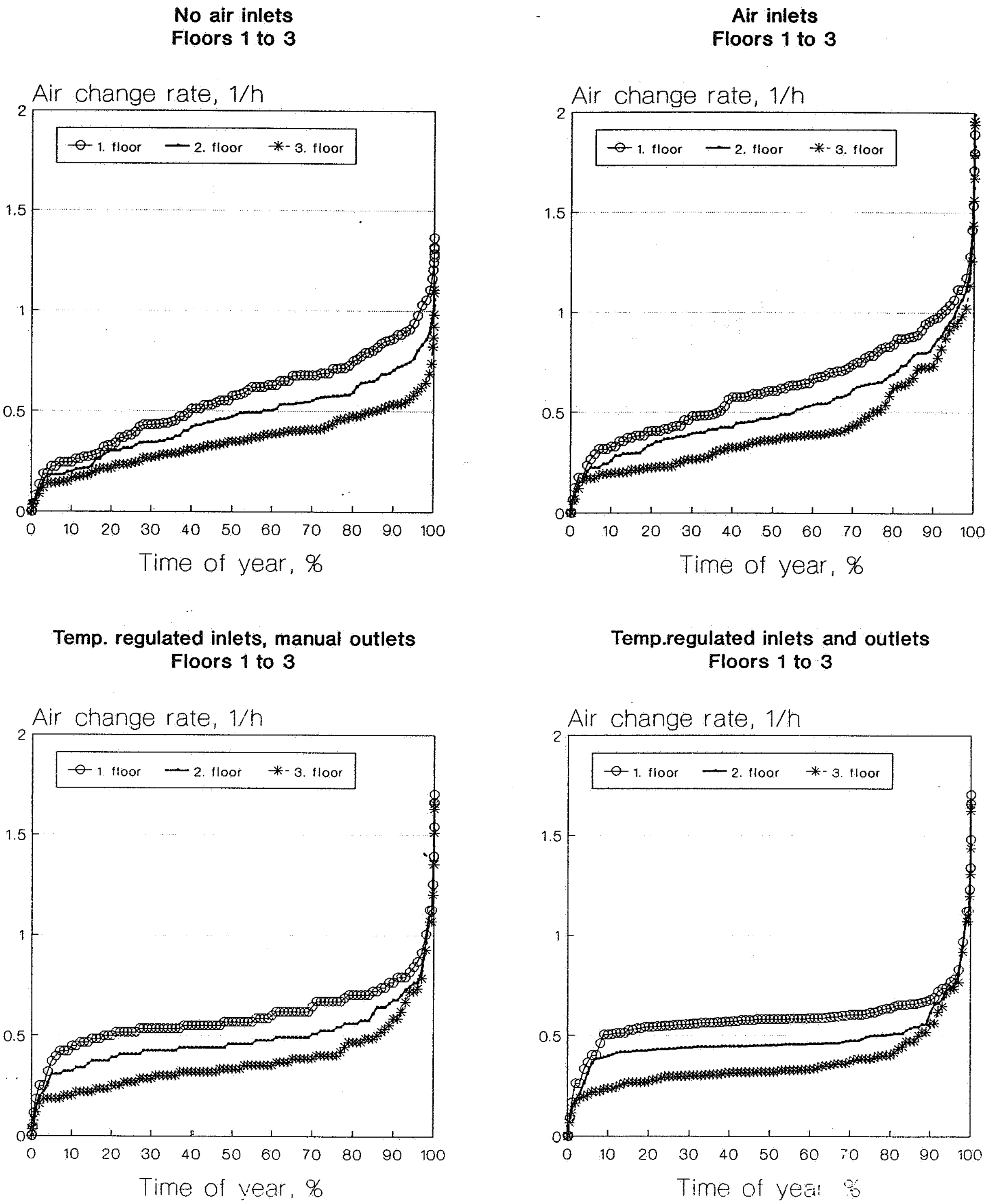
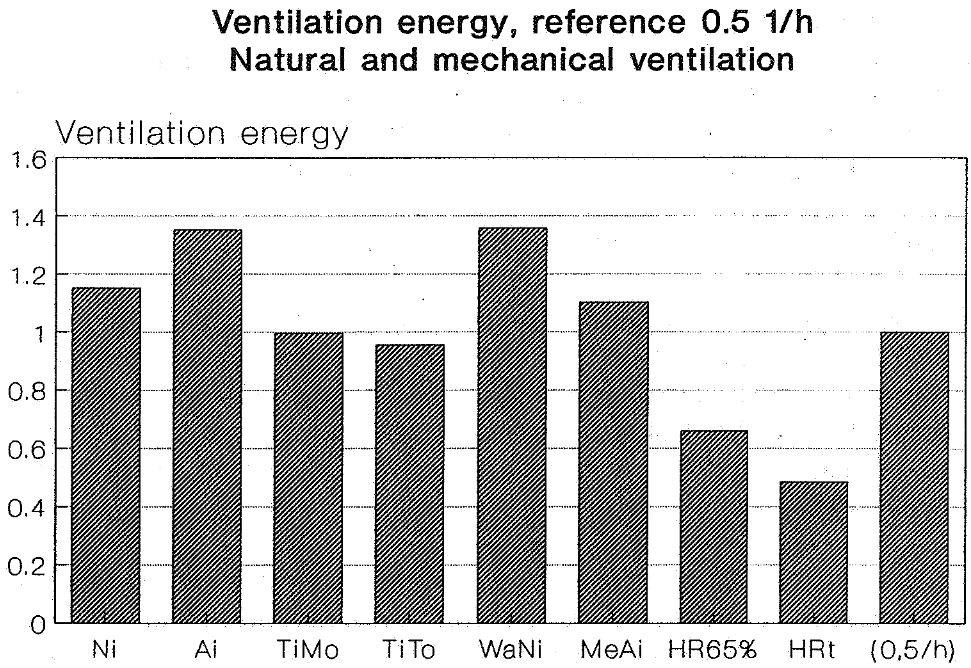



*Figure 3. The annual stability of the outdoor air change rate on the three inhabited floors of a naturally ventilated building. The four cases represent different control strategies of air inlets and outlets. The extract airflow rate on the 2nd floor is adjusted to 0.5 1/h in each case at 4.4°C and zero wind velocity. The weather station is Helsinki-Vantaa and the building is in urban surroundings (wind velocity 72% of weather station velocity).*




**Legend:**

| | |
|---|---|
| Ni | No air inlets |
| Ai | Air inlets |
| TiMo | Temperature controlled air inlets, manually controlled air outlets |
| TiTo | Temperature controlled air inlets and outlets |
| WaNi | Wind assisted ventilation, no air inlets |
| MeAi | Mechanical exhaust, air inlets |
| HR65% | Heat recovery, efficiency 65%, supply air 0.4 1/h, exhaust 0.5 1/h |
| HRt | As HR65%, but building air leakage only 0.6 1/h at 50 Pa |

*Figure 4. Ventilation energy of different ventilation systems. The reference value on the right corresponds to a constant airflow rate of 0.5 1/h throughout the year. The heat balance of the building has been simplified by assuming that external energy is needed when the outdoor temperature is lower than 12°C.*

A more sophisticated control strategy makes use of temperature controlled air inlets (lower left graphs in Figures 2 and 3). In this case the extract air outlets are switched manually to the winter position during three winter months (December to February). This case provides good ventilation stability (Figure 3) and low energy consumption (Figure 4).

Finally, the case in which the air inlets and outlets are temperature controlled shows the best performance in terms of annual stability (Figure 3, lower right graph) and ventilation energy.

The simulations show that there is sufficient driving force for natural ventilation in multi-storey residential buildings for most of the year. The system can work well if the inhabitants are willing and able to regulate the air inlets as well as the air outlets. But there are also several possibilities of automating the system. The first step in renovating the system could be the installation of two position air outlets which have been preadjusted separately for each floor in the building. Humidity control of airflows from bathrooms is also an interesting possibility. The next step is to install air inlets that can be controlled manually, according to the outdoor air temperature, or that maintain a constant airflow /3/.

## 4. MECHANICAL EXTRACTION VENTILATION

For better control of extraction airflow rates a fan can be installed on the top of natural ventilation shafts. The large air ducts from each kitchen and bathroom make it possible to have a demand controlled ventilation system. The only problem is the air leakage of old masonry ducts. Due to this leakage it is not possible to use the high pressures which are common in mechanical systems. A study is under way to examine the different possibilities of sealing old ducts.

Demand controlled ventilation should be the aim also in renovating existing mechanical extraction ventilation systems. The problem here is also connected with the existing air ducts that are shared by different floors in this system. Most recent ducts, in particular, are under-sized so that the pressure level in the ducts must be very carefully selected.

## 5. MECHANICAL EXTRACTION AND SUPPLY

A balanced ventilation system has many good properties: the airflow rates to each habitable room are well controlled, noise and dust can be kept outside, and the heat recovery from the extracted air reduces energy consumption.

However, older buildings are often leaky. Balanced ventilation reduces the depressurization of the building and leads to increased infiltration and energy loss. Therefore the energy saving because of heat recovery was only 35% even if the temperature efficiency of the heat exchanger was assumed to be 65% (see Figure 4). The leakage can be reduced by improved sealing on the building. The energy saving will be 50% if the air leakage is reduced by a factor of 4 from the original 2.4 1/h at 50 pascals.

The corresponding annual air leakage can be seen in Figure 5 in which the building air permeability as well as terrain parameters are varied. An important additional parameter is the difference between air extraction and supply which is in this case 0.1 1/h. It will determine the level of building depressurization. It is interesting to note from Figure 5 that the additional air infiltration is directly proportional to the building air leakage at 50 Pa test pressure.

The possibilities of avoiding extensive new ductwork when introducing balanced ventilation will be studied later in the project. An interesting possibility is to use apartment-specific ventilation units and to install the intake and exhaust vents on the outer wall of each apartment. This was shown to be a reasonable solution considering the quality of the intake air /5/.

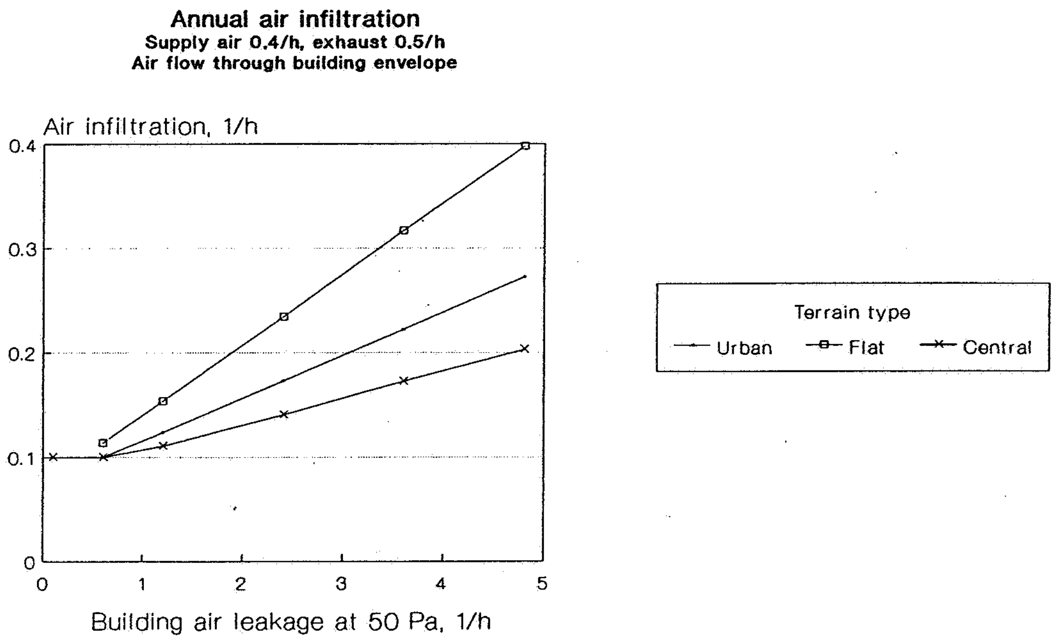



*Figure 5. Annual energy based air infiltration in balanced ventilation. "Energy based" means that the infiltration has been computed from the annual infiltration energy loss.*

## ACKNOWLEDGEMENTS

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