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Long-Term Performance of Residential Ventilation Systems

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LONG-TERM PERFORMANCE OF RESIDENTIAL VENTILATION SYSTEMS

ABSTRACT

Several demonstration buildings were constructed in order to find technical solutions to energy saving and better indoor air quality in the 1980's in Finland. Warm air heating systems were installed in two multi-storey residential buildings and in several single family homes. Heat recovery units were installed in many buildings. During renovation, mechanical supply air and heat recovery units were installed in two multi-storey residential buildings.

Studies on energy consumption and performance of air conditioning systems were carried out in the demonstration buildings. The opinions of occupants were asked. Some of the systems had problems already during the installation and commissioning phase.

A follow-up study was carried out in 1992-1993 on nine of the buildings studied in the 1980's. The aim of the follow-up study was to find out the long term performance of the residential air conditioning and heating systems. The maintenance staff was asked about the malfunctioning of the devices and the need for reparation. The regular maintenance work was discussed, too. The regular maintenance included changing filters every third to sixth month, vacuum cleaning of the heat recovery units every twelfth month (only in the single family homes) and cleaning of ducts and air terminal devices when necessary. Exhaust air flows and pressure conditions were measured during the visits to the buildings.

The main observation was that the normal maintenance work was not sufficient in order to keep the ventilation and air heating systems in planned condition in the long-term. Air flows and pressure conditions of the buildings tend to change in the long term because of e.g. the occupants interaction. The energy consumption of heating and ventilation rose (2 - 39 %) after the follow-up study except in the air heated multi-storey building where energy consumption fell 7 %. However, the heating energy consumption was lower in every demonstration building than in the corresponding residential buildings, due to energy-saving devices.

INTRODUCTION

Several air conditioning systems with new technical solutions were developed in the 1970 - 1980's in Finland. The target was to save heating and ventilation energy. The systems were expected to ensure better indoor air, too. Several demonstration buildings were constructed by public funding and studies were carried out on functioning of devices, energy economy and indoor air. The reported experiences pointed out that the heating and ventilation systems in the demonstration buildings had both advantages and disadvantages. On the other hand the different technical solutions increased the possibilities of occupants to influence on the thermal comfort and ventilation in buildings. On the other hand the sensitivity of the systems to malfunction and the need for maintenance increased. Merely for the realization of the energy economy certain technical devices were necessary. As a rule, the follow-up studies in the demonstration buildings lasted for two heating periods. According to the follow-up studies, it was difficult to estimate the success of the systems in the long-term.

A follow-up study was carried out in 1992-1993 on nine of the buildings studied in the 1980's. The main target of the research was to chart the present ventilation systems and to make conclusions of the changes in the function of systems. The maintenance staff was asked about the malfunctioning of the devices and the need for reparation. Also the regular maintenance work was discussed. The energy and ventilation systems were checked, exhaust air flows and pressure conditions were

measured during the visits to the buildings. The changes in the long-term energy consumption were estimated.

The heating and ventilation systems in the study were:
- two air heating systems in multi-storey residential buildings
- two mechanical supply and exhaust air systems in multi-storey residential buildings
- one solar and earth-heath pump system in a single family house
- one solar heating system in a terraced house
- one air heating system in a terraced house
- two heat recovery systems in multi-storey residential buildings installed during renovation.

The energy and ventilation systems were more complicated than the usual ones (Figure 1) and contained the newest technology. All of the examined systems were still in use, i.e. none of the systems were altered from the original use. In some dwellings of the air heated terraced building electric heaters were installed, but the supply and circulating air devices were functioning normally. The solar heat unit in the solar and earth-heath pump system had not been in use since the 1984.

ENERGY CONSUMPTION

Generally, the total energy (heating of buildings, hot water and domestic electricity) consumption in Finland rose approximately 12 % from the period 1982 - 1985 to the period 1989 -1990 /1/. The heating energy of the demonstration buildings rose 2 % - 39 % after the follow-up studies except for the air heated multi-storey building where the energy consumption fell 7 %. The heating energy consumption (30 kWh/m^{3}a -57 kWh/m^{3}a) of the demonstration buildings of this study was, however, lower than that of the corresponding Finnish residential buildings (63 kWh/m^{3}a), due to the energy saving devices.

The changes in the behavior of the occupants /1/ and the falling energy prices effected the energy consumption in the demonstration buildings. During the follow-up study the occupants were aware of the fact that the energy consumption is studied. For this reason they directed their attention e.g. to the consumption of hot water and to the window opening. After the follow-up study, their interest to energy saving most probably fell. The increase in the energy consumption was biggest in the fuel oil heated terraced house, where the the energy consumption in 1990 was 39 % bigger than in 1979. The real price of fuel oil has fallen most compared to the prices of the other energy sources.

The aging of the heating and ventilation systems in the long-term could also affect to the growth of the energy consumption. For example the control valves did not function as designed. The energy meters had not been calibrated after the installation either.

VENTILATION RATE AND INDOOR AIR QUALITY

In this study the measured ventilation rates were low, 0,02 - 0,71 1/h. Only two dwellings (21 dwellings measured) fulfilled the minimum ventilation rate, 0,5 1/h. In comparison, in study of 251 Finnish dwellings 52 % of the dwellings did not fulfill the minimum ventilation rate (measured with PFT-method) /2/.

Almost in every measured demonstration building the exhaust air flows had fallen with 15 % - 94 %. In one multi-storey building the exhaust air flows had grown with 9 % in the flats on the ground floor. In the same building the exhaust air flow had fallen in the upper floors.

Although the measured ventilation rates were low, the supply air distribution could be considered good in seven demonstration buildings where the supply air was distributed to the bedrooms and

livingrooms. In one of the buildings the supply air was distributed to the halls, in one of the buildings to the stairways.

Five demonstration buildings had warm air heating with air circulation. In three of these buildings the occupants were inquired about the content of dust in indoor air during the studies in the 1980's. From the interviewed occupants 33 %, 52 % and 72 % had considered the content of dust in their home bigger than usually. Circulating air tend to make the supply air devices dirty if the room air is dirty and the filtering is unsufficient.

Air flows and pressure conditions of the demonstration buildings tend to change in the long-term e.g. because of the occupants interaction and dirty ventilation components.

OCCUPANTS' POSSIBILITIES TO CONTROL THE SYSTEMS

Most of the systems had a control panel but that was not available to occupants. On the other hand, the occupants did not even know the normal position of the ventilation devices. The reason was that the use and maintenance instructions had disappeared when the occupants had moved out and new occupants moved in. In order to ensure the proper use of ventilation devices the instructions should be installed on the devices.

In six demonstration buildings the control panels of the ventilation and air circulating devices were located in the dwellings but only in three of them the occupants had the possibility to increase the air flow. On the other hand, the increase of circulating air did not always increase the heating capasity because the outdoor air flow increased, too. In one demonstration building the control system of the circulating air and the supply air temperature was broken.

In two of the air heated buildings the heating and ventilation systems were such that the occupants could not control the air flows or the supply air temperatures. In one of these buildings the occupants had complained of draught. For example the large window in the living room can cause so-called cool radiation in winter time if the supply air is not warm enough. It is important especially in the air heated systems that the occupants could control the supply air temperature.

MAINTENANCE

The heating and ventilating systems were maintained by the service staff or by the occupants. In one demonstration building where the heating and ventilation system was maintained by the service staff the gasgets of the engine doors were worn-out and partly totally missing. The exhaust air filter was not fastened properly. A great proportion of the exhaust air flew to the heat exchanger without filtering. The measured exhaust air flow had fallen 39 % since 1980' and the supply air flow had correspondingly fallen 13 %. In an air heated building the devices were maintained by the service staff. The fans and the filters were dirty. The quality of work done by service staff could be due to the fact that not enough time had been reserved to maintenance work.

In the air heated terraced building maintanance of the devices located in the dwellings should be done by the occupants. The devices were located in the ceiling, which made the maintenance difficult. Part of the devices were very dirty. The reason for the dirtyness could be the lack of knowledge about the importance of cleaning of devices or the difficulties in the cleaning and maintenance.

The cleaning and maintenance work should not be left to the occupants' responsibility. Usually the occupants have no tools to clean e.g. the fans. Even the cleaning of vents can be troublesome. As a rule, the cleaning of air terminal devices requires their loosening. Often the air terminal devices

in the bathrooms are located in the ceiling above the bathtubs. The cleaning of them can be difficult, even dangerous.

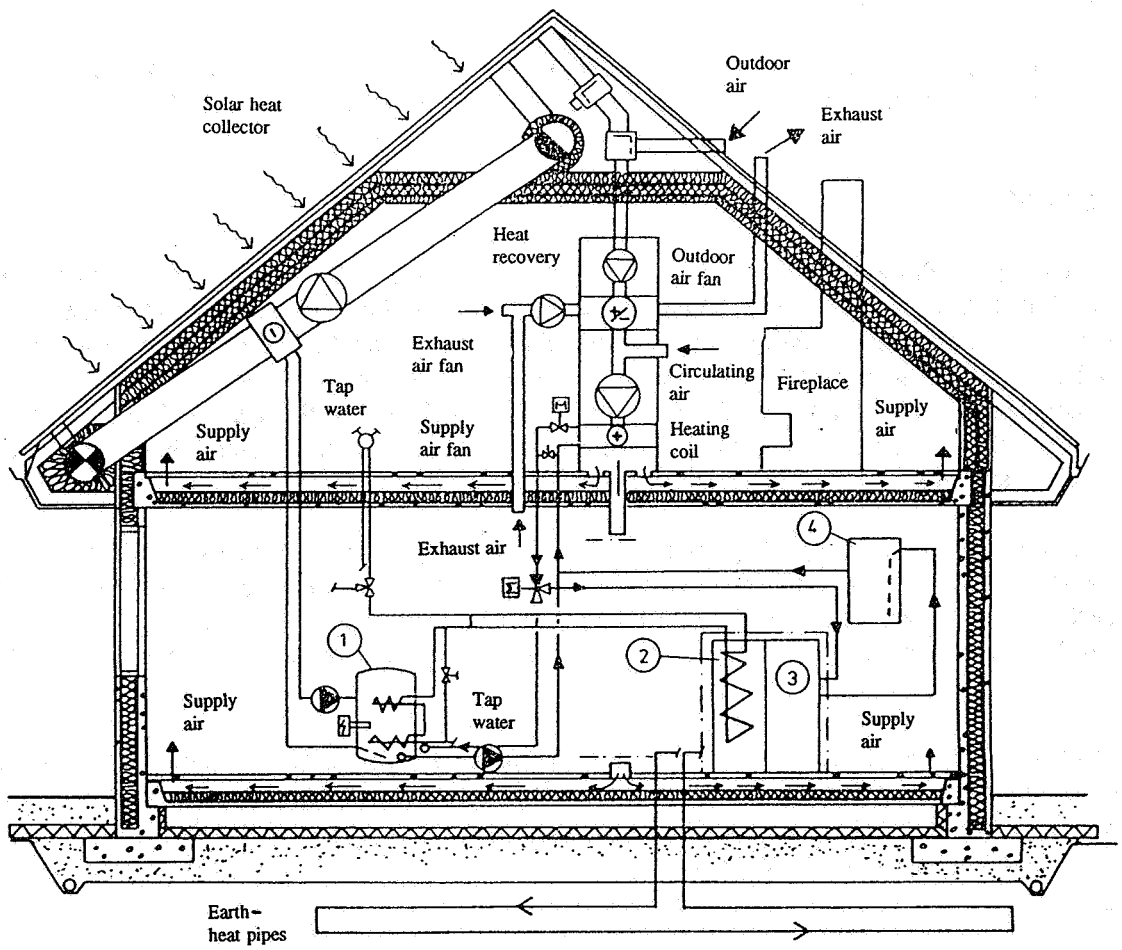
In order to keep the condition of the ventilation systems unchanged in the long-term regular maintenance work is needed and broken parts should be repared as soon as possible.

CONCLUSIONS

In the developing phase of the heating and ventilation systems in 1980's very complicated systems were designed. It was not possible to forecast the difficulties which could appear in the installation and commissioning phase of the systems. Among other things Finland's first warm air heated multi-storey building had the biggest problems with the air locks in the heating water pipes. This problem could have been avoided with careful design and careful installation of the system. The components of the ventilation systems were prototypes, which for example resulted problems in the controll of the installed systems.

In Finland the type aproval of the components of ventilation systems was taken in use in 1983. The type approved products are quality controlled. This procedure has extremely improved the quality and performance of the ventilation equipment. On the other hand the systems are no more designed as complicated as during the developing phase of the ventilation systems in the beginning of the 1980's.

The long-term performance of the heating and ventilation systems requires regular maintenance work and reparing of broken parts as soon as possible. The regular inspections guarantee that the air flow rates do not change too much and the energy consumption does not rise due to malfunction of the heating devices in the long-term.



1 Storage of solar heat
2 Storage of hot tap water
3 Heat pump
4 Storage of heating energy

Figure 1. A demonstration building with solar energy, earth-heat pump and warm air heating systems. This example illustrates a complicated heating and ventilation system. Too many new units should not be examined at the same time.

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