CONVERSION OF A NATURAL DRAUGHT VENTILATION SYSTEM TO MECHANICAL EXHAUST WITH HEAT PUMP - A CASE STUDY

Leif Norell
Fläkt Indoor Climate AB, Stockholm, Sweden

Abstract

Examples of upgrading of natural draught ventilation systems in existing multi-family houses are given in this paper. One exemple describes the installation of a supply and exhaust air system with heat recovery. Another exemple describes the installation of a mechanical exhaust air system in which the existing brickwork ducts have been successfully utilized. A heat pump for the domestic hot water recovers heat from the exhaust air. In this exemple, measurements show that growing problems due to damp and mould have been solved by improved ventilation. The total energy consumption has decreased thanks to the exhaust air heat pump.

Introduction

In Sweden, all new multi-family houses higher than two floors have to have mechanical ventilation. The ventilation system shall secure a continuous ventilation of approximately 0.5 air changes/h in each apartment. Houses comprising more than 12-14 apartments shall have a system for recovering heat from the exhaust air. These are the minimum requirements according to the Swedish Building Code. In pratice, all newly built multi-family houses in Sweden have mechanical ventilation with heat recovery.

Renovation of existing multi-family houses is of increasing importance. In Sweden, the yearly number of renovated apartments exceeds the new production.
In the case of renovation, the formal requirements on a ventilation system are less strict.
Most of the multi-family houses which are scheduled for renovation have natural draught ventilation. As the performance of natural draught ventilation is based on a temperature difference between indoors and outdoors the physical prerequisites for this function do not exist during most of the year. During the winter, however, the risk of too high a ventilation rate is obvious, with draught problems and increased energy consumption as a consequence.

According to the Swedish Building Code (SBN80), the minimum requirements for ventilation improvements when renovating a multi-family house are,

- installation of a kitchen fan
- installation of a bathroom fan
- the ventilation shafts (brickwork) shall be tested to determine whether they are sufficiently air thight
- no measures may be taken that restrict the performance of the natural draught system.

Experience has proven that these requirements can very seldom be met. The brickwork ducts often turn out to be leaky and flexible steel ducts must be inserted to avoid transfer of odours between apartments.

To improve the energy efficiency, the buildings are often additionaly insulated and measures are taken to reduce air infiltration. It is also common that dishwashers, washing-machines and showers are installed or provision is made for their installation. This will substantially increase the the humidity load on the apartment and the ventilation system.
Kitchen or bathroom fans that run intermittently have proved inadequate and are more of a detriment than an improvement to the ventilation.
Consequently, numerous houses which have been renovated the past few years and where the natural draught system has been kept have been affected by damp and mould. This leads to substantial future costs.

In case of renovation, it has therefore become usual to install some kind of system for controlled ventilation.

Balanced ventilation with heat recovery

A good system from the hygienic, comfort and energy efficiency point of view is supply and exhaust air ventilation with heat recovery. This is sometimes the only acceptable system in heavy-traffic areas, as the supply air can then be filtered before it is distributed within the apartment. Individual systems with one AHU per apartment have proven most practical from the installation point of view. (Fig.1)

Simplified mechanical exhaust air system with heat pump

To install a supply/exhaust air system or a traditional centralized exhaust air system may be costly. To reduce the cost, attempts have been made from time to time to utilize the existing brickwork ducts in the chimney stack. For the sake of system stability, restrictors have then been provided at the end of each duct. (p approx. 50-70 Pa at nominal air flow). The results, however, have been poor in most cases, due to leaky ducts.

A different method has been tested by Fläkt. The project has been supported by the Swedish Council for Building Research (BFR) and evaluated in cooperation with the Swedish Institute for Building Research (SIB). In this method, the ducts are regarded as part of the room and the restrictors are placed on top of each duct according to principle shown in Fig. 2. The air flows required for ventilation are small (approx. 15 l/s per duct) and the pressure drop in the ducts are consequently low (1-2 Pa) and the pressure difference between ducts is negligible. The risk of leakage between ducts is therefore small. (SIB Report M85:1)

The method has been tested in a house (24 apartments) in Gävle (Fig.3) in central Sweden. There had been complaints about the indoor climate and traces of mould growth were found in some apartments. The rate of

a air change was measured in each apartment and found to be at an average 0.25 h^{-1} at 4°C outdoor temperature and no wind. The chimneys were cut off above the roof and suction boxes with restrictors (Fig.4) were placed on each chimney. The boxes were connected by tight (class B), round steel ducts (insulated, 60 mm) to a central exhaust air fan. A cooling coil and a filter (G85) was installed (Fig.5) in connection with the fan. The coil was connected to a heat pump which cooled the exhaust air to approx. 3°C before it left the house. The heat recovered was used for heating the domestic hot water. According to the system design, 60 apartments were supplied with heat.
The installation was evaluated in 1984/85 and the results are briefly as follows.

- the indoor climate improved (Table 1). The rate of air change was maintained at 0.5 h^{-1} throughout the year.

- the total energy consumption decreased despite improved ventilation (Table 2).

Table 1. Interview with tenants

Humidity in bathroom	less/ much less	no difference	not applicable
Drying of laundry	67%	20%	13%
Bath/shower	83%	17%	-

Ventilation	better/ much better	no difference	not applicable
Cooking smells	67%	25%	8%
Ventilation of bedroom	96%	4%	0%
Ventilation in general	100%	0%	0%

Tab 2. Heat pump - heat balance

Increase of ventilation (0.25 to 0.5 h^{-1})		+ 42 MWh/year
Heat from heat pump	130 MWh	
Electrical energi heat pump	./. 52 MWh	
Heat recovered	78 MWh	./.78 MWh/year
Saving despite improved ventilation		36 MWh/year

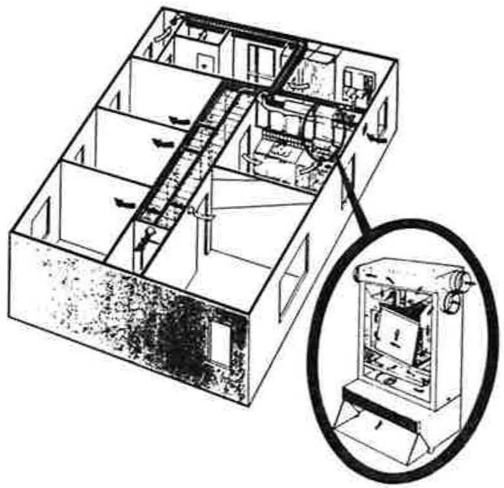

Fig. 1: Individual ventilation system.

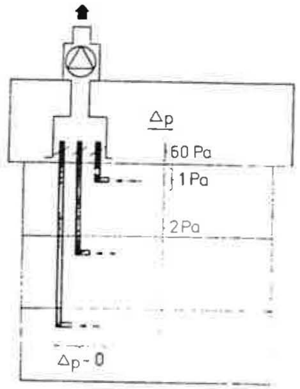

Fig. 2: Restrictors placed on top of duct.

Fig. 3: Test house in Gävle.
Exhaust air unit and duct system visible on the roof.

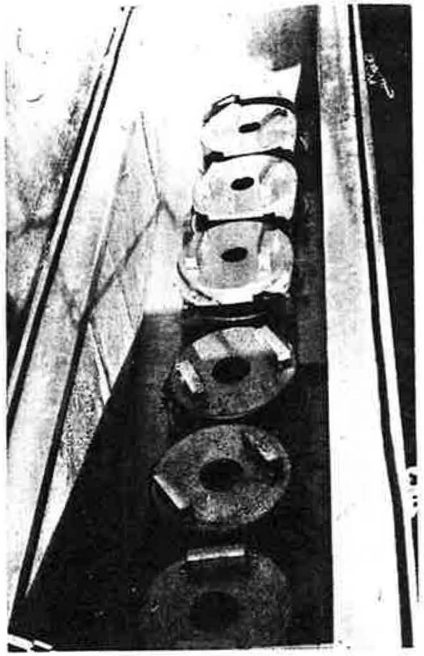

Fig. 4: The restrictors are easily removable for cleaning the ducts. There are two diameters: one for kitchen ducts (15 l/s at Δp 50 Pa) and one for bathrooms (12 l/s).

Fig. 5: The cooling coil is placed in the exhaust air unit.

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INCREASED VENTILATION EFFICIENCY IN ROOMS

Hans Olsson
Hugo Theorells Consulting Engineers
Malmö, Sweden.

Abstract

The ventilation efficiency in a room can be improved by means not used much so far. For a couple of years the author has made studies and tests of a new efficient method for lowering the contamination level in a room. The method is based on the fact that a supply air stream with high induction characteristics will draw secondary air to the outlet. The secondary air containing a maximum amount of contaminants and having a higher temperature than the primary air has, is the most desirable to exhaust in a room. In any type of ventilation system in a room, the supply-exhaust air diffuser or register will considerably increase the ventilation efficiency in the room.

The Background

The author's interest in the efficiency of ventilation in rooms, started 20 years ago when he worked with laminar flow benches and systems, and other equipment used to maintain clean room conditions. He realized that there is often more than one combination of air distribution for obtaining the same level of cleanliness. From laminar flow to single outlet systems. He soon discovered that some advantages of laminar flow could to a certain extent be met by a combination of outlets/inlets. In laminar flow systems one may have stagnant, turbulent air movements caused by machines, people, etc, which may be eliminated by directed air streams. And in ceiling outlet/inlet systems one may have unwanted contamination caused by secondary air movement, which may be eliminated by supplying primary air at floor level or by location of exhaust air inlets where secondary air contains a maximum of contaminants.

The aforementioned is primarily a consequence of one of the fundamental principles in all air distribution, namely: It is the supply air outlet that practically alone creates the ventilation efficiency in a room. One can almost regard the supply air outlet as a fan with inlet and outlet, where the inlet of the fan is the flow of primary air, and the outlet of the fan is the flow of the total air stream. It may also be said that usually more room air is returned to the primary air stream than to the exhaust air inlet, in a balanced conventional ventilation system.

Airborne Contaminants in Room Air

If you look at the settling velocities of particles you will find that particles larger than 10μm settle, with some exceptions, fairly quick and become a cleaning problem. They are suspended only if there is a strong air