DEMAND CONTROLLED HYBRID VENTILATION FOR COLD CLIMATES.

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ABSTRACT

The aim of the project is to study, develop, build (prototype system) and evaluate an energy efficient demand controlled hybrid ventilation system for dwellings in a cold climate. Hybrid ventilation in a cold climate means a ventilation system with low pressure drops, which result in a minimisation of the mechanical energy for ventilation, and that natural driving forces can play an important role. The project is included in the EC research project Reshyvent ”Cluster Project on Demand Controlled Hybrid Ventilation in Residential Buildings with specific emphasis on the Integration of Renewables”. Demand controlled hybrid ventilation is considered to be a promising system of ventilation for the future, where stringent requirements as to energy efficiency and air quality are to be fulfilled.

The ventilation concept is based on an exhaust air system with low pressures drops and a separate fan for each apartment. The fan has a built-in control system for a, according to desire adjustable, constant exhaust air flow independent of the boundary conditions. The desired air flow can be set from a panel in the apartment, but is also automatically controlled by humidity and outdoor air temperature. The outdoor air is preheated by a supply convector. Each apartment has individual control of indoor climate and individual metering of energy use. The system will result in a similar level of energy use for space heating as for a system with balanced ventilation with traditional heat recovery, but lower use of electricity, more user-friendly and improved indoor air quality.

KEYWORDS

Energy efficiency, demand controlled ventilation, dwellings, indoor air quality.

INTRODUCTION

The project is included in the EC research project Reshyvent ”Cluster Project on Demand Controlled Hybrid Ventilation in Residential Buildings with specific emphasis on the Integration of Renewables”. Demand controlled hybrid ventilation is considered to be a promising system of ventilation for the future, where stringent requirements as to energy efficiency and air quality are to be fulfilled.

The results from a technical procurement for demand controlled ventilation for new Swedish dwellings has been the starting point for the development of a demand controlled hybrid ventilation system for cold climates (Blomsterberg 2002). The work has been supported by Reshyvent work packages: market survey, integration of renewable energy, regulations and standards, design parameters, calculations and performance predictions, control strategies, terms of references for components and systems, and urban impact.

The development and expected performance of the prototype system and the system itself is described below.

GENERAL PHILOSOPHY AND ASSUMPTIONS

The task was to develop a concept for demand controlled hybrid ventilation for apartments in a cold climate. Today's ventilation systems, of which most are mechanical, in Sweden often have the following characteristics:

- Actual air flow rates deviate from design values due to deficiencies in system design, adjustment and uncontrolled influence of users (Sandberg 1994, Månsson 1998)
- The use of bathrooms have changed, increased moisture load due to increased shower frequencies and installation of washing machines (Gaunt 1985) with associated risks of moisture and mould problems.
- Mechanical ventilation in apartment buildings usually has an almost constant ventilation over time. Thus it is independent of variations in loads such as moisture, odours, cooking fumes, number of persons present, which results in excessive use of energy. There is a considerable energy savings potential in using demand controlled ventilation (Månsson 1992).
- Today's ventilation systems are often associated with draught problems (Engvall 1992, Andersson 1993). This is especially true for well insulated buildings, where the outdoor air enters behind the radiator.
- Ventilation systems fulfilling design air flow rates often create noise problems (Andersson 1993, Blomsterberg 1995).
- Many ventilation systems include the possibility of increasing the air flow in the kitchen when cooking. The odour capturing ability of fume hoods/fans are often not satisfactory and very often result in complaints concerning cooking odours according to questionnaires (Engvall 1992, Blomsterberg 1995).

A new type of ventilation system is needed, which can solve all or most of the above mentioned problems and which at the same time can reduce the energy use for ventilation (energy for operation and space heating). The most promising system to achieve these goals is demand controlled hybrid ventilation. Such a system should also include features such as individual control of heating and individual metering of energy use.

The first step in improving the performance of ventilation systems based on exhaust fan ventilation and at the same time lowering the energy use is adding demand control. This first step was taken for apartments in an ongoing Swedish technical procurement.

The ventilation concept was to be designed such that the user has the possibility to control the ventilation within the apartment. Nonetheless, the air flow shall automatically increase as needed, to the degree that the minimum environmental and health requirements are met. The varying airflow needs at different operational levels should be met e.g. forced ventilation in the kitchen and bathroom and minimum flow in an empty apartment etc. The ventilation system within the apartment shall be designed with regard to internal loads such as humidity, temperature and carbon dioxide. One desired feature is control of the airflow for each room within each apartment. However, the exhaust air flow for the apartment may only fall below the normal ventilation rate (usually 0.35 l/s(m² of floor area)) in the case of empty apartments.

The ventilation system shall be designed as an open solution; i.e. one that can be integrated with other systems and components from various manufacturers and that allows subsequent adaptations. The ventilation system shall be prepared for individual metering and customer billing. One desired feature is that the technical solutions are prepared for future integration with real property's technical systems and IT-systems for users e.g. time scheduling, internal messages, locking and security systems.

PERFORMANCE SPECIFICATIONS

Indoor climate:
The performance specifications below refer to the occupied zone.
- Outdoor air filtrated by filter class EU 5
- CO_2 < 1000 ppm (12 hour average) and the Reshyvent requirement of CO_2 > 1050 ppm max 500 kppmhours and CO_2 > 1750 ppm max 100 kppmhoursRH < 70 % within 8 hours (bathroom)
- Supply air to living room pre-heated to 5 °C – 30 °C by special convector which minimizes back draft, wind effects and night ventilation
- Indoor temperature 19 °C – 23 °C
- Air velocity < 0.15 m/s (winter) and < 0.25 m/s (summer)
- Outdoor air flow normal operation 0.35 $l/(sm^2)$, the ventilation rate to be based on the number of persons living in the apartment, which means that there are cases when the flow rate will be below 0.35 $l/(sm^2)$
- Outdoor air flow empty apartment 0.10 $l/(sm^2)$Air change efficiency > 40 %
- Cooker hood odour capturing ability > 75 %
- Thermal comfort, 90 % of the time < 10 % PPD
- Pressure difference indoor - outdoor < 15 Pa
- Sound pressure level from HVAC – Swedish class B: 26 dBA for rooms and 35 dBA for kitchen (agreed Reshyvent 35 dBA)Sound pressure level from outside – Swedish class B: 26 dBA for rooms and 35 dBA for kitchen (agreed Reshyvent 35 dBA)

Energy efficiency
- SFP exhaust system < 0.5 $kW/(m^3/s)$
- SFP balanced system < 1.0 $kW/(m^3/s)$
- SFP balanced system with heat recovery < 1.5 $kW/(m^3/s)$

System stability
- Ventilation system must tolerate window opening
- Demand controlled ventilation must not cause lasting changes in indoor air temperature
- Air flow stability 25 – 50 % (good)

System flexibility
- Open solution - allowing mixing of systems and components from different manufacturers

Operation and maintenance
- Individual metering of heating and electricity
- Accessibility for adjustment, cleaning, service
- Measurability of air flows
- Instructions and user friendliness

MAIN CHARACTERISTICS OF THE PROTOTYPE SYSTEM

The system is mainly developed for installation in new apartments, but can also be used for refurbishment.

General

- individual co-ordinated control of heating, indoor temperature and ventilation i.e. for each apartment
- individual metering of energy use, ventilation and indoor temperature, to motivate the users to operate their apartment in an energy efficient manner
- LON-based BEMS, enabling improved operations monitoring
- low pressure drops in ventilation system, to contribute to low use of electricity for ventilation
- control of humidity in bathrooms in order to avoid moisture damage to the building
- passive stack and wind (wind catcher) assisted exhaust fan ventilation, where the fan can be turned off e.g. when no one is at home.

Ventilation in apartments

- one self regulated flow constant volume flow EC fan per apartment
- exhaust air terminal devices in bathroom, lavatory and kitchen
- outdoor air inlets with back flow damper, in façade of bedroom and living room
- pre-adjusted normal ventilation as a function of number of persons, the number can be set by the user
- high efficiency cooker hood with manually forced ventilation with timer
- lowered ventilation when no one at home, manual or automatic (controlled by burglar lock of entrance door or pre-set timer) control. The fan can be turned off.
- lowered ventilation at night in living room, manual or automatic (pre-set timer) control
- relative humidity controlled ventilation in bathroom i.e. preventing lowered ventilation if high humidity level and no one at home.

Ventilation of common areas

- demand controlled ventilation of common areas like stairwell, bicycle storeroom, apartment storerooms, laundry room, technical rooms or central air-to-air heat recovery from exhaust air to supply air (to some of the common rooms)

Space heating apartments

- supply air to bedrooms pre-heated by supply air radiator
- bedrooms heated by radiator
- supply air to living room pre-heated to 18 °C by special convector with back draft damper
- living room heated by radiator and convector
- indoor temperature 19 °C – 23 °C
- the radiators are controlled as a function of outdoor and indoor temperature (thermostat)

EXPECTED PERFORMANCE

The performance of the supply convector, the fan and the control system have been thoroughly tested in a laboratory and proven to fulfil the performance specifications. However the characteristics and the built-in control of the fan should be further improved. CFD-simulations of the risk of draught from the supply convector shows a considerably lower risk than from traditional outdoor air inlets. A four-storey apartment building with the developed ventilation system has been simulated by the work package on calculations and performance predictions. The main goal has been to determine the influence, on infiltration, exfiltration, and air flows and spread of pollutants between apartments, of wind and stack effect coupled with fan operation (hybrid ventilation) for different air airtightness levels, control strategies and ventilation rates. Other goals have been to determine the energy use for heating and use of electricity for ventilation, as well as the indoor air quality. A comparison with a reference system will be made. Preliminary results from the predictions are promising.

The expected energy savings have been estimated by hand calculations to be 50% of the ventilation heat losses for an apartment with an floor area of 80 m^2 (see table 1). Savings which are not accounted for above are: individual metering, fan electricity, indoor temperature compensation of forward temperature. The specific fan power has been determined to be 0.2 kW/(m^3/s).

TABLE 1
Ventilation heat loss energy savings, for an apartment, thanks to demand controlled hybrid ventilation.

Measure	KWh/year
1. Basic adjustment according to number of persons saves on average 9 l/s. Varies with family size from 0 – 18 l/s. 8 h/day.	1 200
2. Night position (-20%) saves on average 4,2 l/s during 8 h , raises the air quality in the bedrooms	180
3. No one at home position (8 l/s during 8 h)	560
Total	1940

The expected energy savings will have a straight payback of 8 years (see table 2).

TABLE 2
Estimation of yearly energy savings, MWh for an existing apartment building.

Total measured for 72 apartments	890
of which domestic hot water	201
Savings thanks to demand control	140
Individual metering of space heating 10 %	55
Space heating control 10 %	49
Individual metering of domestic hot water 15 %	30
Total savings	274
Total savings per apartment	3.8
Payback assuming 1750 Euro additional cost and 0.06 Euro/kWh	8 years

The main demands and expectations of the customers (apartment building owners/developers) as regards ventilation systems are: low sound and draft level, good controllability, reliability, robust, aesthetic and easy to maintain and clean (Blomsterberg 2004). Noise and draught are common sources of complaints from occupants. The hybrid ventilation system being developed aims to meet these demands and expectations, and to be energy efficient.

The prototype system is designed to be more reliable, more user-friendly, better in operation and service than the existing ventilation systems. The overall performance is expected to be better. The ventilation system will be quieter than mechanical ventilation systems.

SUMMARY AND DISCUSSION

A prototype demand controlled hybrid ventilation system for cold climates has been designed, with low pressures drops and one constant volume air flow EC fan for each apartment. According to laboratory tests the main individual components fulfil the performance specifications. There is however potential for improving the characteristics and built-in regulation of the fan. The system will result in a similar level of energy use for space heating as for a system with balanced ventilation with traditional heat recovery, but lower use of electricity, more user-friendly and improved indoor air quality. The system incorporates individual metering of energy use, ventilation and indoor temperature to motivate the users to economize on energy. The main market is new construction of apartment buildings, but could also be retrofitting of existing dwellings (Blomsterberg 2004). The estimated investment cost of the ventilation system is lower than traditional balanced ventilation with heat recovery, but higher than exhaust fan only without heat recovery. Ideally a LCC analysis should be applied.

The next planned step, which is beyond the scope of Reshyvent, is a full-scale demonstration project in a real building. Useful results are expected from an ongoing demonstration project on demand controlled exhaust fan ventilation in 25 new apartments (Blomsterberg 2002).

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