TECHNICAL PROCUREMENT OF DEMAND CONTROLLED VENTILATION FOR DWELLINGS – BASED ON PERFORMANCE SPECIFICATIONS

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ABSTRACT

Swedish dwellings often have mechanical ventilation with an almost constant air flow independent of variations in loads. The performance of these ventilation systems is often not satisfying. The occupant habits have changed e.g. increased moisture load. Therefore a technical procurement for energy efficient demand controlled ventilation systems was initiated.

First the building regulations were analysed, then the parameters relevant for indoor air quality in dwellings and the energy efficiency potential were determined. Directions for the technical procurement including detailed performance specifications were produced. The proposed ventilation systems were evaluated using calculations and laboratory tests.

The performance specifications included maximum levels of carbon dioxide, relative humidity, sound, and a minimum ventilation rate (no one at home), odour-capturing ability for cooker hood, maximum use of electricity for ventilation etc. Two of the proposed ventilation systems fulfilled the specifications and were tested in an apartment and found to perform satisfactorily.

KEYWORDS

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

INTRODUCTION

Most Swedish dwellings, built after 1960, have mechanical ventilation with a ventilating air flow that is almost constant over time and independent of variations in loads (moisture, odours, cooking fumes, number of occupants etc.). Many dwellings do however have a cooker hood in the kitchen, but usually not a very efficient one. The performance of these ventilation systems is often not satisfying according to the compulsory performance checks (Månsson, 1998). The requirements on air quality have increased, besides there are many examples of sick buildings. The occupant habits have changed e.g. the moisture load in modern bathrooms has increased due to higher shower frequencies and installation of washing machines.

In order to improve the performance of ventilation and simplifying ventilation systems, assuming no heat recovery is required, without increasing the energy use or even lowering the energy use, would be to demand control ventilation in future dwellings (Månsson, 1993). A development of such a system has therefore been initiated by JM (Swedish builder), the Swedish National Energy Administration and the Local Investment Program of Stockholm. The development was carried out with a technical procurement for energy efficient demand controlled ventilation systems (Blomsterberg, 2002). Components for demand controlled ventilation exist already today, but there is no real experience of advanced and flexible ventilation systems for apartments. The aim was to initiate a development of new systems for demand controlled ventilation in apartment buildings. The base of the project was the requirements of the buildings code and requirements from users and property managers. The technical systems should be comprehensive ensuring the overall performance i.e. taking into account ventilation, indoor climate, environment, operation and maintenance.

METHODS

Associated with the project has been a control group with representatives from the Swedish Energy Administration and the Local Investment Program in Stockholm, and a purchaser group with a number of developers (JM, LKF, PEAB, Galvegårdarna, Svenska Bostäder, NCC), and the National Board of housing, building and planning. The technical procurement was divided into four steps:

1. Technical competition with evaluation based on theoretical calculations and laboratory performance testing of selected components.
2. Installation and testing of the most promising systems in an apartment
3. Full scale installation and testing in an apartment building (not yet concluded)
4. Performance monitoring and evaluation of the apartment building (not yet concluded).

The work with the technical competition has meant the development of directions for the technical competition. These directions include detailed performance specifications, a model for calculating the life cycle cost, a program for testing of components and for theoretical calculations. The overall aim of the performance specifications was to ensure a well performing system. The specifications cover several areas: indoor climate, energy efficiency, system stability, operation and maintenance, sustainability and costs. The specifications are on general level e.g. robustness, aesthetics, and on a detailed level e.g. air flow rates.

Preceding the development of the directions, the building regulations were analysed, a theoretical study was carried out to determine the parameters relevant for the indoor air quality in dwellings and the influence of ventilation. The potential for energy efficiency related to ventilation was determined (space heating and use of electricity for ventilation).

RESULTS

Demand controlled ventilation in dwellings – building code requirements and possibilities

Requirements on indoor air quality and ventilation in dwellings are mainly given in the Swedish buildings code (Byggregler, 1999). The requirements on the ventilation system include a minimum outdoor air flow rate, that pollutants should be removed, and a minimum air change efficiency. The outdoor air flow must not be lower than 0.35 l/(s and m^2 floor area) during the time the rooms are used. Any other time the air flow rate may be reduced if no health hazard or damage, neither to the building nor to the building services engineering system, arise. In the Swedish building code advice is given as to the exhaust air flow rates from different types of rooms in order to fulfil the requirements concerning removal of pollutants. In the Swedish building code requirements on the performance of the ventilation are given, but no advice as to the reduced outdoor air flow rates or exhaust air flow rates when the rooms are not used i.e. in principle when applying demand controlled ventilation.

The experience from other studies of e.g. an apartment building for persons with allergies (Blomsterberg, 1996) show that measures carried out to arrive at low emissions of pollutants from surfaces can enable a reduction of air flow rates. The study showed that for a dwelling with normal occupancy it can be acceptable, as to minimum relative humidity, maximum CO_2, formaldehyde and TVOC, with an air change rate lower than 0.35 l/(s and m^2), assuming that most of the air in the entire apartment can be utilised e.g. an air exchange between individual rooms within the apartment. It is however difficult to determine how much the ventilation rate can be lowered when no one is at home. When dimensioning the air flow rate it is important to take into consideration the actual demands in order to obtain an optimal indoor climate. The humidity level in bathrooms can be decisive for the dimensioning, which can be met by increased ventilation rate at demand. If low ventilation rates are to be sufficient, then emissions from the building, furniture etc. must be sufficiently low. Lower ventilation rates facilitates fulfilment of other requirements on e.g. minimum relative humidity, draft, sound levels from mechanical ventilation and low use of energy. The conclusion is that the main parameters relevant for the indoor air quality in dwellings are humidity, CO_2, cooking fumes and odours.

Energy use

The energy use for space heating and operation of fans are usually reduced if the ventilation rate is reduced. A reasonable assumption is that the ventilation rate in a two-bedroom apartment with an average family of four can be lowered from 0.35 l/(s and m^2) to 0.10 l/(s and m^2) during 8 hours per day Monday to Friday i.e. a reasonable assumption as to time when no one is at home. The same order of magnitude of reduction of ventilation rate was the conclusion of a Danish study (Bergsoe, 2000). This means a reduction in ventilation during 2184 hours in a year, which results in an average ventilation rate of 0.28 l/(s and m^2) instead of 0.35 l/(s and m^2). This reduction for an apartment (without heat recovery on the ventilating air) in Stockholm results in a reduction in ventilation heat losses of 20 % or 10 kWh/(year and m^2) and a reduction in use of electricity for ventilation of 25 % if the fan is regulated by a frequency transformer (Blomsterberg 1997).

Performance requirements

The technical solution shall be designed such that the occupant has the possibility to control the ventilation within the flat. Nonetheless, the air flow shall automatically increase as needed, to the degree that the minimum environmental and health requirements are met. The ventilation system shall be designed such that the varying air flow needs at different operational conditions can be met, e.g. forced ventilation in the kitchen and bathroom and minimum air flow in an empty apartment etc. The ventilation system within the apartment shall be designed with automatic control with regard to internal loads such as humidity, temperature and carbon dioxide.

Examples of performance specifications are: the mean value over 12 hours of CO_2 content in indoor air less than 1000 ppm, the relative humidity of the bathroom's moistest place below 70 % within 8 hours, air speed in the occupied zone less than 0.15 m/s for winter conditions, outdoor air flow rate for an empty apartment of 0.10 l/sm^2, air change efficiency higher than 40 %, odour capturing ability of cooker hood higher than 75 %, specific fan power if exhaust fan ventilation less than 0.75 $kW/(m^3/s)$, requirements on operation and maintenance, and system stability and flexibility.

Evaluation of the technical competition

Out of seven received proposals four were discarded due to incomplete technical descriptions of the proposed systems etc. The three remaining proposals are all based on mechanical exhaust ventilation with preheating of the incoming outdoor air. Proposal 1 and 7 include a central exhaust air heat pump, while proposal 5 include one fan for each apartment and does not include any heat recovery. Proposal 1 and 5 preheat the outdoor with a supply air convector, while proposal 7 preheats with a supply air radiator.

All three proposals enable demand controlled ventilation including the minimum air flow rate when no one is at home. There are only minor differences between the systems. None of the systems allow individual control of the ventilation in individual rooms. The principle for demand control can be characterised as follows:

- Proposal 1: continuous demand control in bathrooms using a relative humidity sensor (located in the exhaust air terminal device) with higher priority than the minimum ventilation, and in the kitchen a cooker hood controlled by a timer and the range temperature. The fan is centrally installed and frequency regulated.
- Proposal 5: forced ventilation in bathrooms controlled by a relative humidity sensor (located in the bathroom) with higher priority than minimum ventilation when no one is at home, and in the kitchen a cooker hood controlled manually and by a timer. Each apartment is equipped with a rotational frequency regulated low energy fan.
- Proposal 7: forced ventilation in kitchen or bathroom simply means that the ventilation is shifted between the two rooms.

The systems have the following main characteristics of importance to the energy use:

Proposal	1	5	7
Demand controlled ventilation (0.35 l/sm^2 to 0.10 l/sm^2)	Yes	Yes	Yes
Demand controlled ventilation, forced	Yes	Yes	Yes
Heat recovery	Yes	No	Yes
Estimated specific fan power ($kW/m^3/s$)	1.0	0.5	1.0

The component testing showed that all component related performance requirements are fulfilled, except that problems with draft can occur in certain cases within the occupied zone. The three proposals are likely to have problems in fulfilling sound class B according to Swedish standard for sound classification of dwellings i.e. the sound reduction of the facade (Svensk Standard, 1996). The proposals were judged to have some shortcomings as to comprehensiveness, robustness and aesthetics. The proposals were given the opportunity of further development, which proposal 1 and 5 used. These proposals were then considered to fulfil all requirements.
Energy calculations for a planned apartment building show that the three proposals fulfil the energy requirements for space heating according to the Swedish building code. Proposal 1 and 7 have much lower energy use thanks to heat recovery (exhaust air heat pump). Calculations show that it is possible for proposal 1 and 5 to fulfil the relative humidity requirements for bathrooms. Proposal 7 is not likely to meet the requirements. The requirements on CO_2 level in bedrooms can, according to calculations be fulfilled for all three proposals. Calculations of the investment costs show that the cost of demand controlled ventilation systems vary from somewhat more expensive to the double cost of a traditional Swedish mechanical ventilation system.

Proposal 1 and 5 were installed and tested during three months in an apartment each. The systems performed satisfactorily i.e. in the beginning the testing there were some problems with the components, commissioning and control system. Next step will be full scale testing in 25 apartments during an entire year.

DISCUSSION

Only 7 proposals were submitted to the competition, in spite of information to the press, direct contacts with potential proposers and letters of invitation. The reason for so few participants was probably that the performance specification was very ambitious and thereby requiring a great effort of different competence, which only very few have been able and interested in providing. It is of course more difficult to carry out technical procurements of systems than components. The competition has, however, contributed to a technical development. None of the major companies within the field of building services engineering participated in the competition.

Two proposals were considered to fulfil the performance specifications and suitable for full scale testing, after further development had been made. It had not been possible to choose a winner, as it was considered that some of performance requirements could not be met in a real building and there were some shortcomings as to comprehensiveness, robustness and aesthetics. Proposal 1 and 5 fulfil the sound requirement concerning sound reduction of the facade according to the Swedish building code, but not according to class B in the Swedish standard for sound classification of dwellings. After further development the class B requirements can be fulfilled, assuming the exterior sound level to be lower than 55 dB (no major trafic). Life cycle cost calculations was presented by one proposer and only partly by the other proposers, in spite of the fact that a simplified method was given in the directions.
The full merits of demand controlled ventilation for dwellings will not be possible to determine until the full scale testing in 25 apartments have been concluded.

CONCLUSION AND IMPLICATIONS

The technical procurement has so far resulted in two possible systems for demand controlled ventilation of apartments. The developed systems include comprehensive thoughts with individual control of heating and ventilation. The final evaluation will take place in 25 apartments, during 2003. The testing in two apartments indicated that, in order to ensure the performance, the components have to be chosen carefully and the co-ordination between control of indoor temperature, supply air temperature and ventilation must be smart. Careful fine-tuning and follow-up of the performance of the heating and ventilation system are required. The fine-tuning has to take into account the needs of the occupants. The supply convector depending upon location has to be sound proofed.

The crucial parameters, for demand controlled ventilation in dwellings are relative humidity, CO_2, cooking fumes, and odours.

Demand controlled ventilation in dwellings will be further studied and developed on a European level within an EC funded research projects “Cluster project in Demand Controlled Hybrid Ventilation in Residential Buildings with specific emphasis on Integration of Renewables”. Participating countries are the Netherlands, Belgium, Switzerland, Sweden, France, Denmark, Portugal, Norway, Greece, the Czech Republic, Slovenia, Poland, Latvia and Malta.

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