#5989

Ventilation for Energy Efficiency and Optimum Indoor Air Quality
13th AIVC Conference, Nice, France
15-18 September 1992

Poster 9

A New Ventilation Strategy for Humidity Control in Dwellings.

J.B. Nielsen

Danish Building Research Institute, Dr. Neergaads Vej 15, 2970 Hoersholm, Denmark

Synopsis

This report presents the results from the registration throughout a month of relative humidity, temperature and outdoor air exchange as well as the concentration of carbon dioxide in each room of an inhabited single family house, in which all rooms are ventilated by a mechanical balanced ventilation system with variable air volume. The outdoor air rate is controlled by the relative humidity, which is kept on a value adequate to reduce the living conditions for house dust mites and prevent condensation on the indoor surfaces of the building.

Due to the demand controlled ventilation of each individual room a higher efficiency for reducing water vapors in the dwelling as a whole is likely to be achieved. The results show that it was possible in the context of Danish outdoor climate to maintain humidity conditions that is anticipated to reduce the number of house dust mites in all rooms of a dwelling during more than five months of the year. In all the months the mean daily mechanical ventilation rate is estimated to be 39 % below the level recommended by the Nordic Comitee on Building Regulations and in the Danish Building Code. At the same time indoor condensation was avoided on poorly insulated surfaces of the building. The concentration of carbon dioxide was below the level recommended in national ventilation standards.

Synopsis

Ce rapport présente les résultats de l'enregistrement pendant un mois de l'humidité relative de l'air, des températures, du renouvellement d'air de l'extérieur ainsi que de la concentration de dioxyde de carbonique dans chaque chambre d'une maison individuelle habitée, les chambres étant ventilées par un système d'aération méchanique et balancé avec un volume d'air varié. Le volume d'air de renouvellement est régle par l'humidité relative, qui est maintenue à un niveau suffisant à réduire les conditions d'existence des mites de poussière de maison et à éviter la condensation aux surfaces intérieures de la maison.

Grâce à la ventilation réglée selon les besoins dans chaque chambre de la maison, une meilleure efficacité de ventilation est prévue quant à la réduction d'humidité dans la maison entière. Les résultats démontraeint la posibilité, dans le contexte du climat extérieur danois, de maintenir des conditions d'humidité qui réduisent le nombre de mites de poussière dans toutes les chambres d'une maison individuelle pendant plus que cinq mois de l'année. Pendant toute cette période, le volume moyen d'air de renouvellement a été jugé être 39 % au-dessous du niveau recommandé dans le règlement danois de bâtiment. En même temps la condensation intérieure à été évitée aux surfaces mal isolées de la maison. La concentration de dioxyde de carbonique été inférieure au niveau recommandé dans les normes nationales de ventilation.

1. Introduction

A high concentration of humidity in the indoor air of a building forms growing conditions for house dust mites and mould. Both house dust mites and mould can cause allergy with human beings. In addition, rot and mould may seriously damage the construction of the building. The criteria in building codes and ventilation standards for mechanical ventilation of dwellings have the primary aim of securing the exhaust of humidity from the indoor air, and thus avoiding the disadvantages of too high humidity concentrations. The use of mechanical ventilation guarantees a minimum level of ventilation in dwellings. However, if the ventilation has the same air volume regardless of the ventilation need, the outdoor air exchange and the use of energy for heating may in certain periods be unnecessarily high. Therefore, it is obvious to attempt to regulate the ventilation rate by humidity and only ventilate *where* and *when* humidity occurs. This can be done through a ventilation system which has individual control of air volumes for each room of a dwelling. For instance, humidity in the indoor air can be kept on a level which is just sufficient to prevent condensation on indoor surfaces of the building and below 45% of relative humidity which is the limit necessary to reduce the growth of house dust mites (1,2).

The research results are further described in (7).

2. Purpose

The purpose of the above project was to examine if demand controlled mechanical ventilation with humidity as a regulator can assure:

- The maintenance of an indoor climate with satisfactory physical health conditions, i.e. conditions that reduce the occurrence of house dust mites and fungus spore to a minimum in all rooms of a dwelling.
- The avoidance of condensation on indoor surfaces of the building.
- A reduction of the ventilation needs throughout the majority of the year compared to those recommended by the Nordic Comittee on Building Regulations (2) and in the Danish Building Code (3).
- The elimination of the need to adjust the mechanical ventilation system during and after installation.

3. Method

3.1 The dwelling and its inhabitants

A mechanical ventilation system controlled by humidity was installed in a new, 3 room single-family house with a net area of 68 square metres. The house has two inhabitants who are both retired. Once a week during the registration period both inhabitants filled in a questionnaire concerning their indoor activities susceptible of affecting the amount of indoor air humidity.

3.2 The ventilation system

The ventilation system has variable regulation of the air volume and injects air into all rooms including kitchen and bathroom. The system exhausts air from the bathroom and the scullery. The scullery is connected to the kitchen. A regulating damper in the inlet ventilating duct for each room regulates the air volume. The inlet and exhaust performance of the ventilation system is regulated in accordance with the opening or closing of the five regulating dampers. The ventilation system and the regulating dampers receive their regulating signal from humidity and temperature sensors placed in each room and in the inlet ventilation duct. In the kitchen there is also a manually controlled cooker hood which is not connected to the ventilation system.

3.3 Principles of regulation

The ventilation need for each room is determined by indoor and outdoor air humidity and temperature. The relative humidity in a room should be kept below 45%. In addition, the outdoor air supply must be sufficient to avoid condensation on indoor surfaces. The ventilation system was preset to a performance that will prevent condensation on windows with 2 layers of glass.

The regulations in building codes also aim at removing indoor air pollution. However, if the sources of pollution do not at the same time emanate humidity, the ventilation rate for the tested ventilation system can be insufficient. That is why a minimum ventilation rate of 10 l/s is maintained regardless of the humidity control indicating a lower acceptable air volume.

To ensure that the ventilation rate is not unnecessarily high in the case that the outdoor air already has a high humidity and thus poor or no dehumidification potential, the ventilation rate is set to a maximum of 35 l/s, as recommended in (2,3). A high outdoor air humidity is defined as when the inlet air at room temperature has a relative humidity of more than 40%.

3.4 Control and registrations

Every one minute the ventilation system controller records the temperature and the relative humidity in each room and in the inlet ventilating duct. On the basis of these humidity registrations, the settings of the regulating dampers and later on the ventilation rates are gradually modified in order to meet the indoor ventilation rate control criteria.

As a basis for estimating the indoor air humidity and indoor air quality as well as the regulation possibilities of the ventilation system, the following registrations have been made every 10 minute during more than one month of winter:

- temperatures and relative humidity in each room and in the inlet of the ventilating duct
- carbon dioxide concentrations in each room
- air supply to each room
- total exhaust air volume

The time constant of the humidity and temperature sensors was less than 10 seconds.

4. Results

4.1 Registration period

Since the winter during which the registrations were made was exceptionally warm, only the six coldest nights and the six coldest days have been used for the analysis of indoor humidity and carbon dioxide conditions. During the above registration days and nights, the mean outdoor temperature was 4.2°C and the mean outdoor air humidity was 3.69 g vapour/kg dry air.

For the analysis of the ventilation rate the registrations for more than one month have been used.

4.2 Activities of the inhabitants

On an average, the inhabitants occupied the house for more than 21 out of 24 hours. They felt no need for airing and never opened the windows. Twice a day pillows and eiderdowns were shaken out of the front door for about five minutes. Clothes was washed in a washing machine and dried by hanging in the bathroom and the scullery. During the test period the average cooker hood exhaust was 0.06 l/s.

4.3 Outdoor air supply

The maximum performance of the ventilation plant is registered to be 58.9 l/s, when all regulating dampers are open. This corresponds to an air exchange of 1.3 h^{-1}. If only one regulating damper is open, the maximum possible air exchange in one room can be from 1.4 h^{-1} in the living room to 7.7 h^{-1} in the bathroom.

The infiltration of outdoor air into the building has been registered in a summer period at different wind velocities to be between 0.06 h^{-1} and 0.12 h^{-1}. During the winter registration period of this project, the infiltration of outdoor air is estimated to be 0.15 - 0.20 h^{-1}.

Because of the ventilation being controlled by individual demands it was not necessary to adjust the ventilation system after installation.

4.4 Humidity and temperature

During the six days and nights for which humidity conditions have been analysed the mean indoor temperature varied between 20.5° C in the bedroom and 23.7° C in the living room. The cumulative relative frequency of relative humidity in the kitchen, the bathroom, and the bedroom is shown in figure 1.

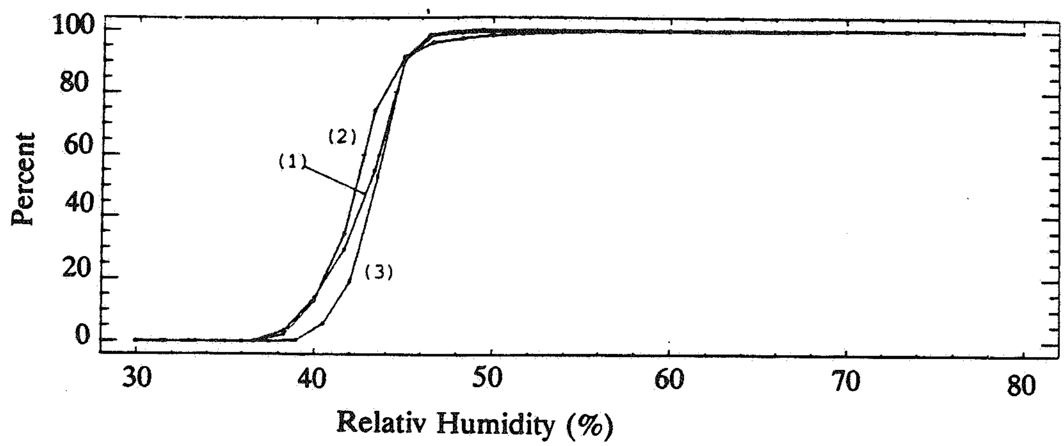

Figure 1. The cumulative relative frequency of relative humidity in the kitchen (1), the bathroom (2), the bedroom (3).

The limit of 45% of relative humidity which is the criterion of preventing the growth of house dust mites has been exceeded in the bedroom and the bathroom for about 10% of the registrations. At a relative humidity of 47% the limit is only exceeded in 1% of the registrations as regards the bathroom and 5% as regards the bedroom.

Condensation on the indoor surfaces of a building occurs first on the surfaces having the lowest temperature. In relatively new Danish buildings these surfaces are the windows and the window frames. Figure 2 shows the limiting cases for the bathroom when condensation is about to occur on thermo windows with two layers of glass having a 12 mm air filled space between the layers.

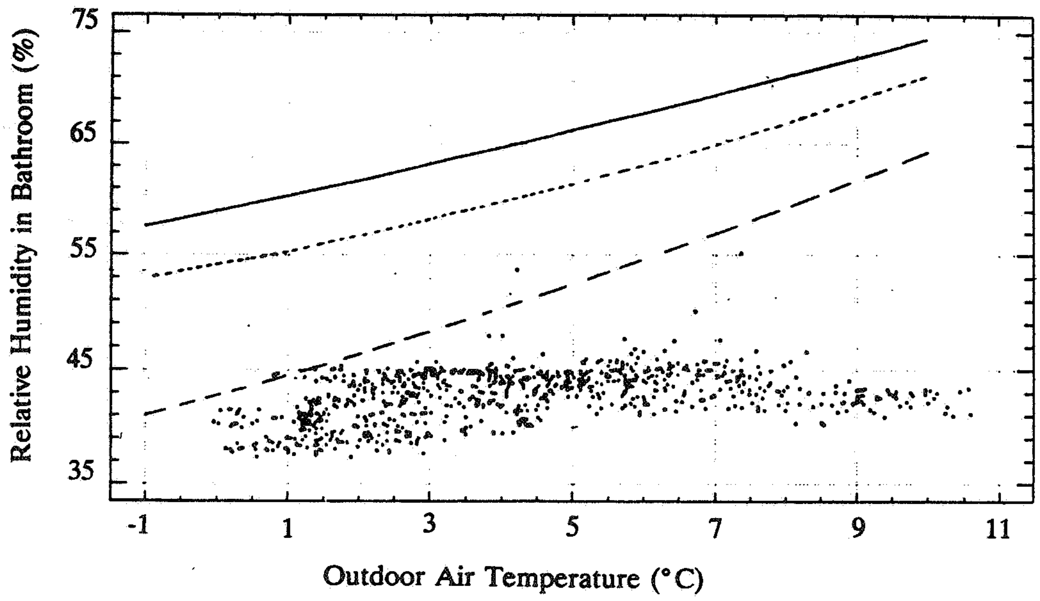

Figure 2. The limit of the occurrence of condensation in the middle of a 1 meter tall window when a curtain has been drawn (--) and when a curtain does not over the window (--), as well as at the lower edge of the window (...) when a curtain does not cover the window.

The limit of the occurrence of condensation is based on a calculation of the heat transmission of a 1 meter tall window. The heat radiation and the heat convection have been calculated individually and apply for the average glass surface.

Only in a few cases the limits of the occurrence of condensation are exceeded in the middle of the glass surface when the curtain has been drawn, and only two times when the curtain does not cover the window. At an outdoor temperature of about 0°C this curve crosses the ordinate axis of relative humidity at 45%. At an outdoor temperature of less than 0°C the ventilation system must be controlled uniquely by the criterion of condensation, if condensation is to be avoided in the middle of the glass surface with curtains drawn. It was not possible to test the ventilation system controlled by humidity at lower outdoor temperatures than 0°C.

For the other four rooms similar comparisons of limits of the occurrence of condensation and registrations of relative humidity have been made. In these rooms the excesses of the limits of the occurrence of condensation have been even fewer than shown for the bathroom. The inhabitants did not observe condensation on the indoor window surfaces during the test period.

The total amount of humidity developed in the air of the dwelling is calculated to be 12 l of water per 24 hours on an average.

4.5 Carbon dioxide
Interviews with the inhabitants show that they do the same things at approximately the same time every day and night, i.e. they rise, have breakfast, lunch, and dinner, rest, watch television etc. at the same time of day. So it was possible to predict in which room the inhabitants would be at which time. Knowing the concentration of carbon dioxide at different times in each room, it was possible to assess the amount of carbon dioxide that the inhabitants were exposed to during six days and nights. In less than 12% of the time the concentration exceeds 1000 ppm and in less than 2% of the time it exceeds 1200 ppm.

5. Discussion

5.1 Humidity
The criteria that aim at keeping the relative humidity of the indoor air below 45% an at preventing condensation are met in the test building at mean outdoor temperatures below 5.9°C. In Denmark, the mean outdoor temperature is below 5.9°C during 44% of the year. It has not been analysed whether the indoor humidity criteria will be met at mean outdoor temperatures of 5.9°C and above.

In a new study (4), the difference between the absolute outdoor and indoor humidity was registered in 36 single-family houses with constant mechanical exhaust. In 97% of the houses the difference between the absolute outdoor and indoor humidity was below that registered for the present project's test dwelling. In 53% of the houses the total outdoor air volume was below the outdoor air volume of about 30 l/s registered in the test dwelling. At a lower mean inlet air volume more humidity per m^3 air was removed from the test dwelling than from the single-family houses on an average. Therefore, the tested ventilation system seems to give a more efficient exhaust of humidity than a ventilation system with a constant ventilation rate.

In (4) the development of humidity per 24 hours was found on the basis of humidity registrations in each of the 36 single-family houses. The indoor humidity was registered in the living room. A similar registration for the test dwelling shows that the total development of humidity is 11.5 litres of water per 24 hours. Only 20% of the houses in (4) are above this level. Therefore, the amount of humidity developed in the test dwelling can be considered sufficient to test the regulation possibilities of the ventilation system.

The analyses in the present test project show that the emanence of humidity from the building construction can be removed through the building infiltration. Therefore, humidity emanating from the building does not affect this project.

The two inhabitants were both retired, but still physically active. However, if the house was inhabited by a family with teenage children, the ventilation need may be higher.

5.2 Carbon dioxide
The registered concentrations of carbon dioxide are generally below the recommendations of 1000 - 1500 ppm found in national ventilation standards (8).

5.3 Outdoor air supply
In dwellings having mechanical ventilation *with a constant ventilation rate,* the exhaust air volume from kitchen and bathroom must be at least a constant of 35 l/s according to the standards in (2, 3).

In (5) and in (6), 38.9 l/s and 33.3 l/s respectively are the recommended values for the mechanical air volume in a dwelling having the size of the test building.

In the present project the possibilities of reducing the mechanical ventilation have been estimated according to the standards and recommendations in (2, 3) and the defined regulation criteria. In (3) an outdoor air exchange of 0.5 h^{-1} is considered to be necessary as a basic ventilation rate in dwellings. This is also part of the estimation. Table 1 shows the estimated reduction of air volumes and air exchange and the period of reduction within the context of Danish outdoor climate.

Standards of comparison	Are reduced to	Reduction in percentage	Period of reduction
35 l/s	21.4 l/s	39%	6 months
0.5 h^{-1}	0.36 h^{-1}	27%	4 months

Table 1. Reduction of air volumes and air exchange

Since an air exchange of 0.5 h^{-1} does not correspond to an air volume of 35 l/s, the two periods differ.

In general, the reduction of air volumes and air exchange in a building will substantially depend of the number of family members and their habits.

5.4 Other pollutions

In the present project the humidity of the air has been used as the parametre of regulation. However, if the pollution for which we are ventilating is for instance gases emanating from furniture and building materials or radon rather than humidity, mechanical ventilation with humidity as the regulation parametre may not be sufficient.

Relatively new results of research indicate that the amount of gases which emanates from furniture and building materials differs considerably. Therefore, a bad choice of furniture and building materials can set the parametre of regulation of air volumes in dwellings with mechanical ventilation. In such cases the ventilation rate obtained by a ventilation system controlled by humidity can be insufficient. This can be avoided by increasing the minimum ventilation rate. Only that means that the reduction obtained of air volumes and air exchange will be less.

5.5 Consumption of electricity

The present project does not involve registrations nor considerations concerning the possibility of saving electricity obtained through the reduction of mechanical ventilation.

6. Conclusion

By the use of a mechanical ventilation system controlled by humidity in all rooms of a dwelling it has been possible to achieve humidity conditions which in the context of Danish outdoor climate can prevent the growth of house dust mites for more than five months of the year. Throughout this period the outdoor air volume supplied by the mechanical ventilation was estimated to be 39% less than stated in the standards and recommendations of (2,3). At the same time, damages to buildings caused by condensation on poorly isolated surfaces are avoided, and the concentration of carbon dioxide in the indoor air is below the maximum level recommended in national ventilation standards.

It has not been taken into consideration whether the demand controlled ventilation system will be profitable and generally applicable.

7. Perspectives of the project

The present project will be followed by an analysis that includes the investigation of mechanical ventilation in 32 flats. Half of the flats will have a ventilation system controlled by humidity, and the other half will have constant ventilation. Comparative studies of the two types of mechanical ventilation will be carried out regarding humidity, outdoor air supply by mechanical ventilation and infiltration, consumption of electricity by the mechanical ventilation system, and the use of energy for heating.

The mechanical ventilation controlled by humidity will only be used in bathrooms and kitchens, and each exhaust ventilator will cover several flats. An internal control of differences in pressure in the ventilation system will regulate the distribution of the exhaust air volume among the flats. In each room there will be a venthole for the supply of outdoor air. The venthole openings and the ventilation rate are regulated simultaneously. The criteria of humidity control will remain the same.

8. Collaboration

The project has been made in collaboration with Danfoss System Controls and with the engineering company Esbensen F.R.I. and is financed by the Danish Ministry of Housing, National Building and Housing Agency.

References:

(1) Korsgaard, J. The effect of indoor environment on the house dust mite. In P.O. Fanger and O. Valbjørn(eds): Indoor Climate, Danish Building Research Institute, Copenhagen 1979.

(2) Nordic Comittee on Building Regulations, NKB, Indoor Climate - Air Quality, publication no 61E, June 1991.

(3) National Building Agency. Danish Building Regulations for small Buildings. 1985.

(4) Bergsoe, N.C. Investigations on air change and air quality in dwellings. CIB W67 Symposium on Energy, Moisture and Climate in Buildings. Rotterdam 1990.

(5) Ministère Francais de la Construction et du Logement. Code de la construction et de l'habitation. 1982.

(6) Verein Deutscher Ingenieure. Lüftungsanlagen Für Wohnungen, VDI 2088, Dezember 1976.

(7) Ministry of Housing, National Building and Housing Agency. Behovsstyret mekanisk ventilation. Fugt som reguleringsparameter - et pilotprojekt. Copenhagen, April 1992.

(8) Raatschen, W., Demand controlled ventilating System. State of the Art Review. Energy Consumption i Building and Community Systems Programme, Annex 18, February 1990.