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Warm Air Heating with a Constant High Supply Air Flow Rate without Recirculation

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Synopsis

In Halmstad a multi-apartment house has been built with air carried heating. Fresh air was used as the only heat carrier. To improve the air quality it was decided to not use circulation flow, which is normally required for air carried heating. The heating requirement was obtained with a higher air flow than what the standard requires. This also implied improved air quality. The standard specification states 0.5 changes per hour as the minimum requirement, but in Halmstad the house was ventilated with 0.7 - 1.0 changes per hour. The drawbacks resulting for this (greater ventilation losses, with operating faults to fans) have been solved with a high degree of heat recovery and frequency control of the fans.

The measurement results indicate that the increased ventilation losses on the basis of a higher ventilation flow were 11 kWh/year m^2. The operating faults for the fans increased from 60 W to 110 W per apartment. The tenants experienced an improved air quality in comparison with a control group. All the air in the apartments was replaced with fresh air within two hours. Despite that the installed system is not fully commercially developed the costs for installation and operation were the same as for conventional heating and ventilation systems.

In the next generation of similar systems the experience of this project will enable the reduction of the safety margins during planning. During the planning it was decided to dimension the system for 1.3 changes per hour. During practical operations 1.0 changes per hour has proved to be sufficient. This implies that it is possible to reduce the duct dimensions, use smaller fans, smaller air-to-air heat exchangers, and remove the frequency controls on the fans. This enables a considerably cheaper system and a better acoustic climate.

1. Background

1.1 Ventilation

In Sweden the minimum requirement with respect to the ventilation (see Ref. 1) of apartments is regulated for the different types of rooms and the activity which takes place. In addition there are requirements as to which type of air is to be supplied to the different rooms.

In living rooms the "outdoor air flow rate" shall be at least 0.35 ltr/sec m^2 of the floor area.

Even in bedrooms the "outdoor air flow rate" shall be 0.35 ltr/sec m^2 of the floor area. However, in addition to the requirement for outdoor air flow there is a requirement on an "air flow rate" of 4 ltr/sec per bed. The concept of air exchange includes both outdoor flow and transferred air.

Other apartment areas can be ventilated with "transmitted air" only. Depending on the type of room there are different requirements as to how large the flow shall be.

Example

A three-room apartment is to have the following ventilation flows and types of air.

Example

Type of room	*Living area* m^2	*Outdoor air* l/s	*Transferred air* l/s	*Exhaust air* l/s
Bedroom 1*	12.6	4.4		
Bedroom 2**	12.8	4.5	3.5	
- Living room	30.7	10.7		
- Kitchen	13.4			10.0
- Bathroom	4.2			10.0
- Hall	7.7		2.7	

*) one bed
**) two beds

In the example above it was the exhaust air for the kitchen and bathroom which were critical for the dimensioning of the apartment, the total outdoor flow rate was 20 ltr/sec. This corresponds to 0.4 air turnovers per hour. A typical value for the number of turnovers per hour is 0.5 as per Swedish standard requirements.

During the last five years the debate in Sweden has been intensive as to how much we should ventilate our apartments, and on the use of circulation air.

The reason why the use of circulation air is not favoured is that impurities are thereby distributed to the entire apartment. Arguments that the ducts for circulation air are dirty and contaminate the air have also been presented.

1.2 Heat recovery

Since the end of the 70' s the majority of buildings have been provided with some form of heat recovery. The two methods which have been used for the recovery of the ventilation air are air heat exchangers or exhaust air heat pumps. The different systems are estimated to have an equal share of the market.

The reasons that buildings were provided with heat recovery were on the one hand rising energy prices. and on the other the modified standards (Ref. 2) which required heat recovery when the heat content in the exhaust air was > 50 MW hours/year.

1.3 Insulation

In the standard requirement for the insulation of external walls the requirement for U was up to 1975 0.58 W/m^2 °C. The new standard the next year almost halved the U value to 0.3 W/m^2.

2.1 Test object

In Halmstad a multi-apartment house with 14 apartments has been built during 1989. Since the building is well insulated the power requirement for heating is low. By reasonably increasing the ventilation flows it is possible to supply heat via the ventilation system. The air which is used for heating is outdoor air only. There is no circulation air in the system. To meet the heating requirement of design temperature (-16°C) with a max supply air temperature of 50°C one air change per hour is needed. Depending on the outdoor temperature the number of air changes varies steplessly between 0.7 - 1.0 / hour. In the system there is an air to air heat exchanger. The temperature efficiency capacity of the unit is 67%. The unit is placed in the fan room and supplies all the apartments. Each apartment is provided with a follow-up heating battery which enables the regulation of the temperature in each apartment up to 22°C.

The house is well insulated, the heat transmission ratio of the outer walls in 0.17 W/m^2.

2.2 Results and discussion

The Swedish National Testing and Research Institute (SP) were commissioned by Swedish Council for Building Research (BFR) to make an evaluation during the period Feb 1990 to April 1991 as to how the system functioned with respect to:

- Greater ventilation losses on the basis of higher ventilation flow.

- The air quality.

- The air exchange efficiency.

- Noise from fans.

- Greater operating faults to fans as a result of higher flow.

- Poll investigation of the experience of the tenants as to the indoor environment.

- Economical yield of the system.

The measurements were initiated in connection with occupation of the building in December 1989.

- Function check in connection with occupation.

- Long-term measurements.

- Function check at he end of the project.

The measurements in connection with the function checks have been carried out with intensive measurements. The objective of these measurements was to ensure that the system functioned as intended at the planning stage.

The long-term measurements have been carried out with a data logger which was installed in the building. Via a modem the measurement values have been transferred to a mini computer (VAX) to SP every day. The objective of these measurement was to follow-up energy/power consumption for electricity and heating.

The results form the project are presented in a report, see reference 5.

Measurement results

3.1 Greater ventilation losses on the basis of a higher ventilation flow.

The total air flows to the building and the sub-air flows to the apartments have been measured continuously during the measurement period.
The measurements indicate that the ventilation flow to the building has varied between 0.7 - 1.0 changes per hour.
The mean value for the ventilation was 0.9 changes per hour over the measurement period.

The heat recovery unit's temperature efficiency has been measured up to 67%.

To study the differences in the ventilation losses between a ventilation system which complies with the minimum requirements as per Swedish standards (0.5 changes per hour) and the air exchange which has taken place in the building (0.7 - 1.0), calculations were made in the computer program AXSEL; see reference 6.

From these calculations it was revealed that the ventilation losses increased by 5200 kWh/year for the whole building. The total living area in the building is 475 m^2. The increase in ventilation losses per year thus becomes 11 kWh/m^2 floor area.

3.2 Volatile organic substances

The building's air quality with respect to volatile organic substances was established by absorbing the substances on tenax tubes for a period of one hour. This measurement was carried out in the fresh air duct and in an apartment. The measurements were carried out 16 months after occupation.

These measurements indicated that the VOC content was 170 µg/m^3.
Several of the substances which were identification the indoor air were 2-(epoxyethexy) ethanol, one of many glycol ethers, used in water diluted paints. Phenol, included in different binder agents in flooring of PVC.

In order to study differences in VOC in the outdoor air, measurements were made for one week. These measurements were carried out with the aid of a photo-acoustic
method which registered VOC in the form of methane equivalents every 12 minutes. The measurements were made in the fresh air duct to the building.

The content of VOC proved to vary between 50-65 µg/m^3 of air during the measurement period.

The content of VOC in indoor air is usually less than 200 µg/m^3 as per the experience have of measurements in Swedish apartments.

3.3 Relative humidity content in the indoor environment

The relative humidity content was measured continuously during the measurement period in four apartments. During a three week period in February 91 the RH values read off were registered. During this period the RH was between 30-35%; the indoor temperature was 23°C and the outdoor temperature was -4 °C. The highest level on RH was registered in Apgust -90. During a couple of weeks in August the RH value was 60%, the indoor temperature was 23 °C and the outdoor temperature was 19 °C.

The discomfort limits which we have in Sweden indicate that RH should lie between 30 - 60%.

3.4 Air exchange efficiency

A measure of how efficiently the ventilation air is entered into all the areas in an apartment is the "air exchange efficiency" (see Ref. 3). The efficiency is given in per cent of the theoretical min time taken to exchange all the air in a room. If the efficiency is less than 40%, and the number of changes is 0.5 hour, it will take 5 hours before the air is exchange in the apartment.

The air exchange efficiency was measured in one apartment in the building to 50%. Since the number of changes per hour is 1.0, the air will be exchanged every other hour in the apartment.

A typical value of the air exchange efficiency in a conventional ventilation system is 40 - 50%.

3.5 Noise from fans

The system is dimensioned to handle up to 1.3 changes per hour. The reason for this is that a safety margin was required in the event that the heating did not work as intended. The sound level was measured in two apartments, in the bedrooms and living rooms. The measurements were carried out for the max installed flow of 1.3 changes per hour. The following results were obtained:

Bedroom 1	23 dBA
Bedroom 2	23 dBA
Living room 1	26 dBA
Living room 2	31 dBA

The max permissible sound pressure level as per the Swedish Standard is 30 dBA in bedrooms and living rooms, but since in practical operations 1.0 turnovers/hour has proved to be sufficient the sound requirements have been met.

3.6 Greater operating faults for fans on the basis of the higher flows

To counteract the negative effects of a higher power consumption for the fans they were provided with frequency control. A standard ventilation with 0.5 changes per hour in a building with 14 apartments (the same as the experimental building) requires a fan effect of 400 W per fan.

In view of the fact that the adjustment of the air flows was incorrect during a part of the measurement period there are no measurement results for the fan consumptions during a one year period. But with the experience we have obtained from the measurements during the period when the flows were correctly adjusted we can confirm that a good mean value for the year as to the number of changes per hour is 0.9. With this flow the exhaust air fans consume 600 W and the supply air fans 850 W.

The extra fan effect resulting from the increase of the fresh air flow by almost half in comparison with the Swedish Standard thus becomes 50 W per apartment.

3.7 Polling of the experience of the tenants as to the indoor climate

A poll developed by Örebro's Industrial Medicine department was used to investigate the subjective experience of the tenants as to the indoor climate. The investigation was addressed to adults only. There were too few children for them to be included in the investigation. The response frequency was very high, a full 95%. The investigation was made seven months after occupation. There was a check group of 292 persons for the poll. The poll was divided into two main headings: "environmental factors" and "complaint symptoms".

Environmental factors were dust and dirt, noise, tobacco fumes from others, static electricity, unpleasant smells, dry air, stuffy air, too low room temperature, varying room temperature, too high room temperature, and draughts.

The characteristics which were investigated with respect to "complaints and symptoms" were dry itching, red skin on hands or face, coughing, hoarse throat, irritated or blocked nose, eye irritation, concentration difficulties, off-colour, headache, heavy head, and tiredness.

The investigation indicated that there were more persons with tiredness, heavy heads and headaches than in the check group. The increase was between 20 - 30% of these complaints.

The reason for the complaints could possibly be the result of high contents of volatile organic substances VOC or noise. If the problem is the result of VOC the complains should become alleviated since these diminish powerfully during the first two years.

That noise can result in the type of problems experienced by the tenants is confirmed in other investigations (see Ref. 4).
In the check group, 20% of the persons consider themselves to have complaints with "stuffy bad air". In the experimental building 10% experienced these problems. This would indicate that the tenants noticed a positive effect of the increased fresh air flow with respect to the detectable air quality.

3.8 Economic yield of the system

3.8.1 Investment costs

In the area where the experimental building is located there is a similar building with conventional heating system. A comparison between the investment costs between the conventional system and the experimental building indicates that the cost structures remain the same.

The air heating system which was installed in the experimental building was not commercially tested in any previous installation. During the installation of techniques which are relatively untested in a commercial sense, the cost structure in comparison with more tradition techniques usually tends to favour the traditional system. This relationship usually changes when the techniques have become more generally available, and commercially developed. This is what has occurred in the Swedish small house industry, where today 50% of the buildings have air carried heating where the ventilation system is integrated with the heating system.

3.8.2 Costs for operation and maintenance

Previous multi-apartment buildings which have tested air heating on an experimental scale have in several cases utilized units placed in the apartments. This has proved to imply increased costs for operation and maintenance since the administrator has been obliged to go into every apartment and replace filters. In the building in Halmstad there is only two filters in place in the fan room. Replacement of these filters take place as often as normally required in a balanced ventilation system. According to the administrator the system has not contributed towards the increase of costs for operating and maintenance in comparison with a traditional heating system.

4.1 Conclusion

The general conclusions which can be drawn from the project of heating apartment buildings with fresh air only and an air changes per of 1.0 hour are:

- The increased ventilation losses become less (in this project it became 11 kW hours/year floor area).

- The tenants experienced an improved air quality.

- The relative humidity content lies within comfort limits (30 - 60%).

- The increase in operating faults for the fans does not need to exceed 50 W per apartment.

- A fully developed commercial system will be cheaper than a conventional heating system.

5 Recommendations

In the next generation of similar systems the experience of this project will enable the reduction of the safety margins during planing. During the planning it was decided to dimension the system for 1.3 changes per hour. During practical operations 1.0 changes per hour has proved to be sufficient. This implies that it is possible to reduce the duct dimensions, use smaller fans, smaller air-to-air heat exchangers, and remove the frequency controls on the fans. This enables a considerably cheaper system and a better acoustic climate.

References:

Ref. 1 New building regulations BFS 1988:18
Ref. 2 Swedish Building Standard 1980
Ref. 3 Building-Ventilation Air NT VVS 047
Ref. 4 Journal of Sound and Vibration (1989) 133 (1), 117-128
Ref. 5 Luftburen värme i kvarteret klotet SP-RAPP 1991 E20013
Ref. 6 Computer program AXSEL, Stratos Ventilation

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