AIR QUALITY IN COW HOUSES WITH CURTAIN WALL VENTILATION IN FINNISH CLIMATE

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ABSTRACT

Most Finnish dairy barns – old and new ones – are ventilated with electric fans. Natural ventilation through wall curtains is a new technology in insulated dairy barns in Finland. The first equipment was assembled in 2004 and today it is expected to become a challenging option for dairy farmers. The main object of this research was to find out first how this new technology fits into Finnish climate and secondly what is the of indoor air quality performance. The research had mainly two phases. First a field measurement session was carried out in three selected insulated barns which had been built recently and equipped with curtain walls. The measurements took place between February and March 2006, a period for harsh frost. Instrumentation collected data from inside and outside temperature, relative humidity, wind and air velocity. Carbon dioxide and ammonia were recorded inside the barns as well as radiation and heat flow in the floor. Data was collected into computer data loggers. Secondly a year performance model was simulated according to the measured data. The model results reveal that curtain wall technology can be used in Finnish climate and it gives good air quality even in cold winter time air exchange situations. Summertime air quality is superb compare to electric fan solutions. The only negative points are a few frost days and high relative humidity inside the barn during wintertime.

CURTAIN WALL TECHNOLOGIES IN MEASURED BARNS

The field measurements were done in three cow houses in middle Finland. The oldest barn had been one year in operation and the youngest was brand new. The barns contained 120–140 cubicles. The floor area varied between 960 and 1900 m^2. Wall curtains in all cases were hand adjusted by farmers' intuition. The farmers made a book keeping about curtain openings so that this data was used in the final calculations. The year simulation was made according to animal heat, humidity, CO_2 production, ammonia production, milk yield and forage intake values. U-values in constructions were considered as they were built. Solar radiation, local long time climatic data were added into the formula.

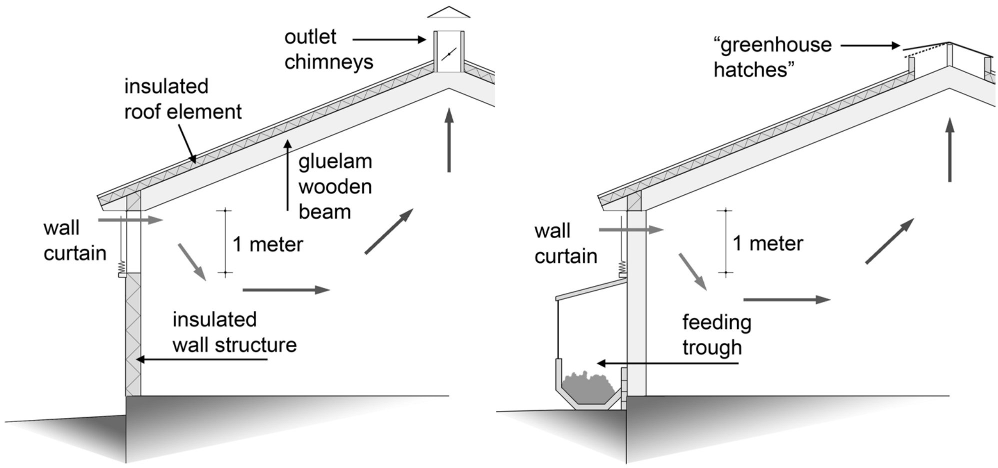

Figure 1. Ventilation inlet and outlet technologies in measured barns. In all cases walls and roof were insulated, the inlet opening was one meter (when fully open) and outlet openings had several types, chimneys and the whole ridge long greenhouse hatches

YEAR SIMULATION FOR VENTILATION AND AIR QUALITY

The year simulation was calculated with a computer program created by VTT researchers. The simulation was based partly to the measured data and a long term weather data from Finnish meteorological institute. The simulation numbers were calculated for a barn with 124 cubicles, floor area 1245 m^2 and volume 6350 m^3. The simulation barn had 80 milking cows and 30 heifers and dry cows. The total continuous energy produced by the animals was 130 kW. The walls and roof were thermal insulated. The floor had no insulation at all.

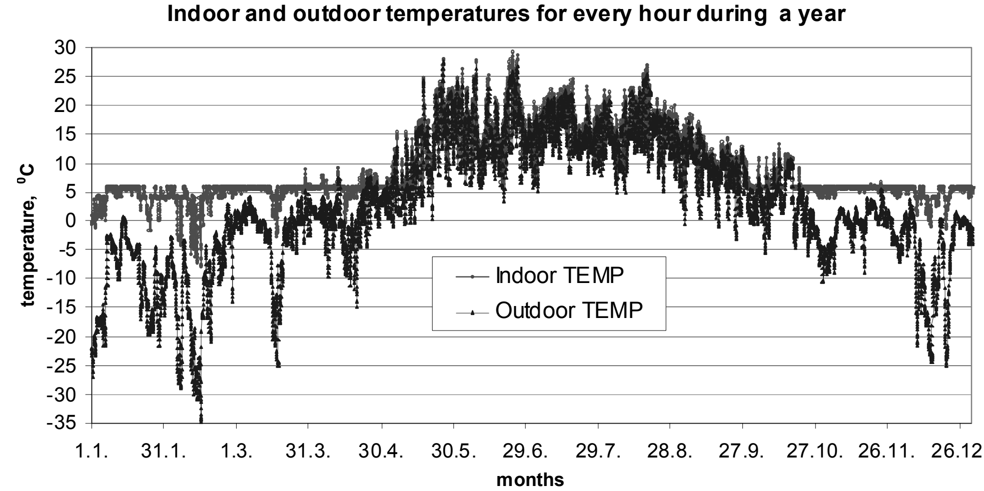

Figure 2. Indoor temperatures according to simulation

The inside temperature will be controlled to maintain +4 – +6°C level through autumn, winter and spring. For a few days in January – February the inside temperature may go slightly under 0°C due to extreme outdoor winter temperatures. The additional heating is needed under –23°C outdoor temperature if the farmer wanted to keep the inside temperature over 0 C. Practically however indoor surfaces, drinking cup or water hoses do not freeze even if the additional heating didn't exist. Summertime indoor temperatures follow outdoor temperatures.

Carbon dioxide is a rather good indicator for air quality and air exchange rate. The simulation indicates that CO_2 concentration is very acceptable. The maximum level in Finland is 3000 ppm. It seems to exceed the limit only for 3,4% of all 8760 hours a year during the coldest periods in wintertime when the ventilation is at its minimum. But in return the level remains mostly at 500 ppm for nearly 6 months a year.

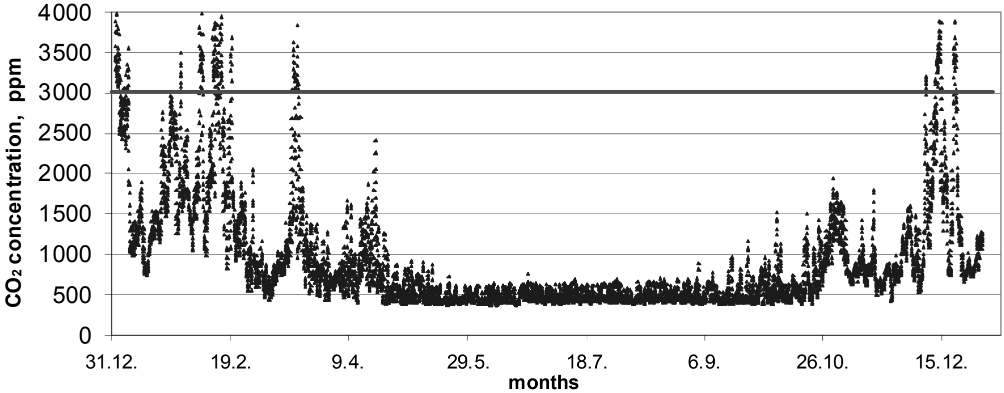

Figure 3. Carbon dioxide concentration according to simulation

The relative indoor humidity is hard to be controlled if judged according to CIGR recommendation for a dairy barn. Relative humidity occurs in intensively during the winter time, sometimes reaching 100% (dots over 100, in figure 4) and then the air becomes foggy. But the relative humidity exceeds the CIGR's 90-rule also between +5 and + 20°C which are springtime, autumn and summer temperatures as well. At the same time the barn can be too dry. This means that the barn is dependent on outdoor circumstances due to summertime day and night variation of temperature and humidity. But still the high relative humidity can be a threat to constructions especially for timber and steel. It also can cause mildew growth and premature decay on wood surfaces.

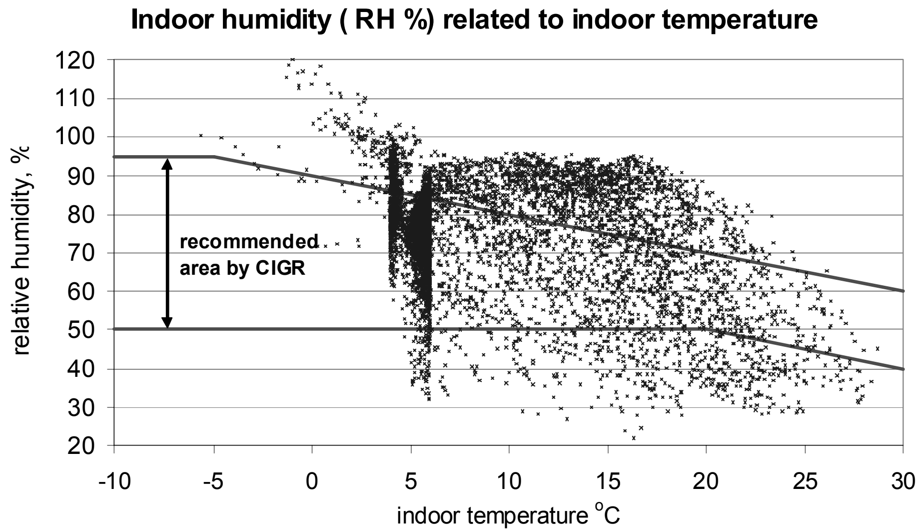

Figure 4. Indoor humidity according to simulation

Technical assembly and detailing of the curtain makes the system vulnerable for air leakages. These leakages are not harmful. On the contrary they maintain the sufficient level of basic air exchange during the cold winter times when the curtain is closed. This feature practically keeps the minimum ventilation rate in proper level.

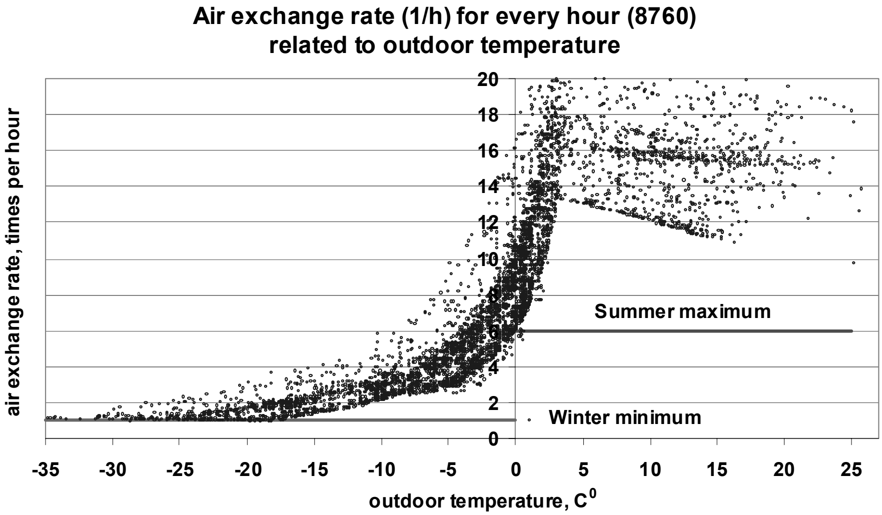

Figure 5. Air exchange rate

The blue dots in figure 5 indicate the air exchange rate (times per hour) related to outdoor temperature. The winter minimum and summer maximum lines are indicate the ventilation rate requirements in Finnish legislation for animal husbandry buildings in agriculture. The winter minimum exchange rate can be achieved even in the coldest periods. When the outdoor temperature reaches 0 C air moves and changes 6–10 times per hour. On a calm summer day air changes approximately 12 times and even 50–100 times on a windy day. The wall curtain system always guarantees minimum exchange and the maximum rate is well beyond requirement. This gives a good air exchange rate and thus appropriate air quality.

CONCLUSIONS

The curtain wall system appears to be an acceptable and functional ventilation concept for insulated dairy barns in Finnish climate if few inconveniences are accepted. These are slight frost days under zero and high relative humidity. In return the ideal temperature + 5°C can be maintained over 7 months in Finnish climate. Gas emissions are always in control and minimum air exchange is good and maximum exchange very good. The system also consumes very little electric power. If the barn of this size had electric fans the annual energy consumption could otherwise be 16000 kWh. The system is also rather silent. These features give a good hygienic production environment for cows in air quality and acoustic environment.