Bernd Möller, Hans-Joachim Müller and Manfred Gläser, Potsdam, as well as Ute Wanka, Köllitsch, and Thomas Heidenreich, Böhlitz-Ehrenberg

Quantitative Assessment of Air Flow inside Naturally Ventilated Animal Houses

Houses can either be acclimated through forced or natural ventilation. Natural ventilation means energy saving and noise reduction, but is also dependent on the reliable functioning of the ventilation principle through the design of the construction cover, as well as the incoming and the outgoing air openings. Sufficient data on the emission and the immission characteristics of naturally ventilated livestock buildings is lacking. For designing animal houses with natural ventilation, as well as for making an eco-relevant assessment of these systems, knowledge about the through-flow in such buildings is necessary. More ideas are given in this contribution.

Dipl.-Ing.Bernd Möller, Dr. Hans-Joachim Müller and Dr. Manfred Gläser are scientists at the Department of Engineering for Livestock Management at Leibniz-Institute for Agricultural Engineering Potsdam-Bornim (ATB), Max-Eyth-Allee 100, 14469 Potsdam, e-mail: *bmoeller@atb-potsdam.de*
Dr. Ute Wanka and Thomas Heidenreich are scientists at the Saxon State Institute for Agriculture.

Keywords

Natural ventilation, air flow, climate in animal houses, emission

Keeping of animals species appropriate demands beside others the compliance with certain climate parameters. In the standard DIN 18910 there are ranges given for the temperature and the air humidity in animal houses. Furthermore there are to find thresholds regarding of CO_2-concentration and air velocity in the animal zone. The heat and mass production of the animals and of their excrements are to dissipate out from the building by suitable ventilation systems, to keep the named climate parameters in the animal zone. This can occur by means of fans (forced ventilation) or by openings in the livestock building (free or natural ventilation). Together with the air volume stream, which flows through the building, emissions (gas, odour, dust and bio aerosols) enter the surrounding. As well as regarding to the function of the ventilation and regarding to the emission, mass flows knowledge about the air volume stream inside the building is of interest. The metrological determination of the air volume stream is especially in naturally ventilated animal houses a problem. The ATB uses in such cases preferable tracer gas methods. The function of these methods will be clarified in the following and results on emissions are shown.

Flow investigations

Beside the animal physiological parameters, which show animal specific differences, the thermodynamic behaviour of the building as well as the air flow conditions in a stable room play a essential role regarding the climate conditions in animal zone and regarding the emissions. Therefore microclimatic investigations should include fluidic analyses. While in the case of forced ventilated buildings by the fresh air system and by the used fans an enforced flow exist, by application of natural ventilation the air flow inside the stable room is affected by local and temporal fluctuations. These fluctuations result by the permanently varying driving forces of the natural ventilation – thermal lift and wind. The investigation of the air flow inside the animal house can be carried out by using the following methods:

- numerical flow simulation
- physical models
- measurements in practice

From the named methods the information received can be increased in the amount (extrapolation of single measurement periods for the whole year) and in the reliability, if these three methods will be used in combination. The Leibniz-Institute for Agricultural Engineering (ATB) is specialized in physical modelling and in measurements in practice. The inclusion of flow simulation takes place in close collaboration between ATB and the Federal Research Centre Braunschweig-Voelkenrode (FAL) [1]. The numerical simulation of air flow pattern in rooms is used for forced ventilation as well as for natural ventilation. For such calculations, especially in case of natural ventilation, the outside climate conditions mainly temperature and wind are taken into account.

To characterize the air flow inside naturally ventilated buildings the ATB applied in model investigations and for measurements in practice the following methods:

- visualisation of air flow by means of particles and recording the air flow pattern (photo or video technology)
- measuring of temperature, concentration and velocity fields
- air exchange measurements by tracer gases (SF_6, CO_2 and Krypton^{85})

The ATB is specialized mainly in application and development of air exchange measurement using the radioactive and inert gas Krypton^{85}. This method has enormous advantages regarding to the temporal and local resolution of the measurements [2].

Selected investigations and results

The ATB has carried out investigations regarding naturally ventilated livestock buildings especially in cattle houses. But also for pig houses and poultry houses measuring results exist. In this article only some examples from cattle houses are presented. The simple

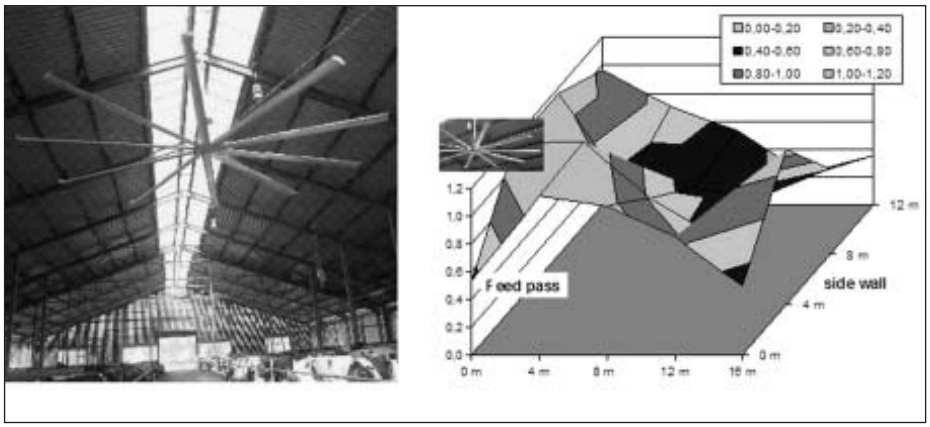

Fig. 1: Ceiling fan (left) and air velocity field 1.2 m above the floor (May 4 th 2006). The velocity values are average values for about 2 minutes

method of flow visualisation by means of smoke generators (theatre and disco smoke) demonstrates the operation mode of the ventilation system. E.g. badly ventilated zones, cold air incidences or zones with high air velocities (draught) can be observed in a simple way. By the air velocity measurement technique the air flow conditions can be quantified. *Figure 1* exemplifies the effect of ceiling fans on the air velocity in the animal zone. By means of such fans e.g. "heat stress" should be avoided in cattle houses during summer time. The air velocity field shows large differences. Near the fan (diameter ~ 7 m) the air velocity of 1 m/s is exceeded. With the distance from the fan air velocity increasing and close to the side wall the outside wind influenced the air velocity in the animal zone.

A further possibility to quantify the flow conditions is the determination of the air exchange rate. By the so called "Krypton method" developed by ATB, inside the animal house up to 40 measurement points can be installed. Therewith local differences can be observed. These differences result from different holding time of the air at different locations in the room, which results e.g. from the variation of wind direction and wind velocity outside. In the simplest way the air volume stream can be determined by averaging over all measurement points. The air volume stream is the product from the air exchange rate and room volume. One example is shown in *Figure 2*. In this diagram different methods to determine the air volume stream are illustrated. About the single methods is the following can be said:

CO_2-balance
The air volume stream results from a balance calculation, which considered the CO_2-production of the animals and the concentration difference between inside and outside the building. The influence of the outside wind can be seen. The deviation between the different methods is partly strong, but there are also time segments with a good agreement (22:00 to 00:00 o'clock). As reason for the deviation it is to be identified that the number of cows in the house is not exactly established (during the milking process not all cows are inside the house) and the circadian fluctuation of the CO_2-production of the animals is in this case not considered.

Air velocity
In the present case (*Fig. 2*) air velocity sensors (anemometer) were installed in the wall openings. The shown air volume stream in *Figure 2* is the product of the average value (every 10 minutes) of air velocity in the opening and of the opening area.

Krypton method
The air volume stream is calculated from the measured air exchange rate in h^{-1} and from the room volume in m^3. The average value is aggregated from 18 measurement points.

Compartment method
The measuring values from the Krypton method is used (one concentration value per second). The stable room is divided in zones (compartments) and every compartment is allocated one Geiger-Mueller counting tube. The courses of the concentration in the single compartments permit to use the balance calculation. This method is described in detail in [3].

The ammonia concentration measuring parallel to the air volume stream measuring allows the determination of the ammonia emission stream. Such results exist at the ATB. The determined values of the ammonia emission streams are comparable to the values of other authors.

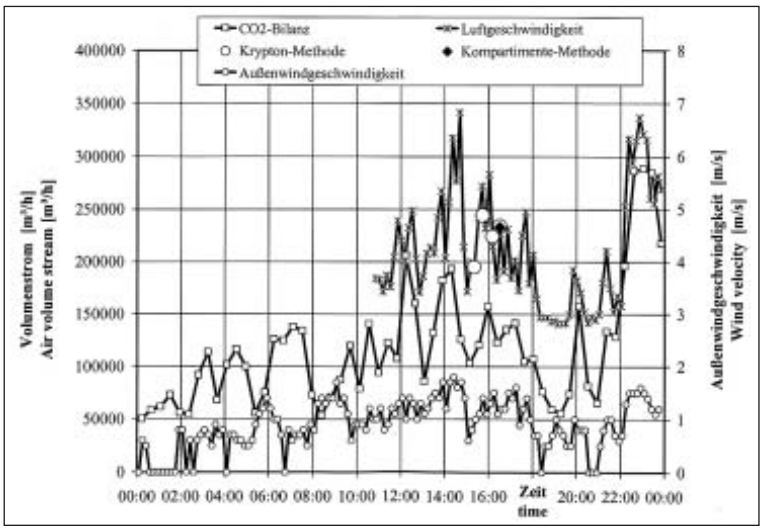

Fig. 2: Air volume stream of a naturally ventilated cow shed (room volume about 5000 m^3) – results from different measuring and evaluation methods (April 20 th 2006)

Conclusion

- Tracer gas methods are well applicable to determine the air volume stream in naturally ventilated livestock buildings
- While the application of Krypton^{85} provide resilient data for short measuring sequences, the CO_2-balance method allows results for longer measuring periods, when considering the variation of the CO_2 production of the animals.

Literature

[1] *Krause, K.-H., H.-J. Müller und S. Linke*: Gaseous emissions from livestock buildings and the dispersion of these emissions in the surroundings. Indoor Air, Peking, 2005

[2] *Müller, H.-J., und B. Möller*: Determination of Air Exchange Rates in an experimental Cattle Housing using Tracer Gas Methods. ROOMVENT'98. Volume 2, pp. 511 - 516

[3] • *Brehme, G.*: Quantifizierung des Luftvolumenstroms in frei gelüfteten Rinderställen mit Hilfe der Kompartimentalisierungsmethode zur Bestimmung umweltrelevanter Emissionsmassenströme. Dissertation, Georg-August-Universität, Göttingen, 2001, (http://webdoc.sub.gwdg.de/diss/2001/brehme/index.html)