DETERMINATION OF AIR CHANGE RATES IN AN EXPERIMENTAL CATTLE HOUSING USING TRACER GAS METHODS

H.-J. Müller, B. Möller
Institute of Agricultural Engineering, ATB, Potsdam, Germa

ABSTRACT

The air stream through a livestock building plays an important role for the inside climate and the emissions from such buildings. Especially for natural ventilated housings the determination of the flow volume leads to some problems. Complicated air stream patterns of the inlets and outlets often make measurements using velocity sensors impossible. In such cases Tracer-gas-methods can be applied.

Inadequate mixing between fresh-air and indoor-air as well as high air change rates are relevant error sources for measurements in natural ventilated barns by using these methods.

Due to the above reasons at the Institute of Agricultural Engineering Bornim a 40 sampling-point system has been developed which is using Krypton 85 as tracer gas. All fourty points are running simultaneously with a maximum sampling rate of one second. Air change rates of up to 1000 h^{-1} are measurable. Techniques and applied devices are explained on a 1:1 scaled experimental cattle housing. Influencing parameters like indoor-flow-pattern, environment-temperature and outside-wind-conditions are recorded and presented along with the results. The method will be compared with diverse others.

KEYWORDS

Air change, livestock buildings, tracer gas method

INTRODUCTION

The keeping of animals in livestock buildings requires ventilation dependent on the kind of animals kept, animal weight, building architecture and outside clima conditions different air volume rates have to be realized. Forced ventilation can be used as well as natural ventilation. Healthy climate conditions for the animals should be provided. Unfortunately ventilation leads inevitable to the emission of dust germs and gaseous pollutants linke ammonia, methane and laughing gas. Odours derived from these gases can cause annoyances as well as environmental damage can be produced by some of the emittet substances. Therefore emissions have to be avoided respectively reduced.

Ventilation systems have to be developed which on one hand ensure appropriate clima conditions for the animals and on the other hand cause low emissions. The air rate through the building plays an important role thereby. Within the scope of the evaluation of ventilation systems air rates of different livestock buildings have to be investigated.

Complicated inlet and outlet conditions especially at natural ventilated livestock buildings make these investigations often impossible when using velocity measurements. In such cases tracer gas techniques may be applied to determine the air rate. Problems with this methods are caused by large indoor volumina (several thousand m³), non-ideal mixing between fresh air and indoor air and particular very high air change rates (up to 100 h^{-1}).

In the following an improved method will be presented which is able to deal with such complicate conditions.

METHODS

Methods used at the Institute of Agricultural Engineering (ATB) have already been presented at the ROOMVENT conference in 1994 (Müller et al. 1994). These methods have been improved in the last years. Tracer gases SF_6 and Kr85 are employed. A multi-gas monitor in combination with a multi-point sampler for 12 sample locations is used to determine the concentration of Sulfur hexafluorid (SF_6), Carbono dioxide (CO_2), Ammonia (NH_3) and Methane (CH_4).

The air samples get sucked off from the sampling points through thin flexible tubes. Since the analysing of a sample lasts 2 minutes, the whole measuring cycle takes depending on the gas to be analysed about 30 minutes.

Reasoned by these long time SF_6 is released continuously into the room. Balance-sheet calculations including the measured concentration and the amount of supplied SF_6 leed to the determination of the volume rate. By employing the radioactive Tracer gas Krypton 85 the decay method is being used. After a single release of the gas the decay curve is measured with different types of proportional counter tubes.

The number of sampling points has been increased from 12 to 40, counting on self was improved to a maximal possible sampling rate of 1 sec. measured parallel at all fourty tubes. To reduce the time effort spent in installing the data transmission and power supply for the counting tubes telemetric data transfer is being proofed for it's practicability in livestock building environments. First tests have been successfully completed. The time formaly spent for laying out cables was significantly reduced. The tests were carried out at an experimental plant.

Figure 1 Natural ventilated experimental cattle livestock building with eaves to ridge ventilation

Sampling points were arranged in constant distances at the building. Two hight levels were applied for fixing the counter tubes.

Following solutions have been found for the distribution of the tracer gas:

1. Continuously displacement of the gas out of a glass flask by simultaneously walking with the flask through the building.
2. Distribution by a system of flexible tubes and use of a pump.
3. To dose the gas into a central part of the inlet air system.
4. To dose the gas into the suction part of a recirculatory van, respectively hot air blaster.

Beside the gas concentrations the environmental conditions like inside and outside temperature, inside and outside air humidity, flow structure of the building (application of smoke tests), outside wind speed and wind quater are recorded simultaneously.

RESULTS

The described measurements took place in summer 1997. The inside and outside clima conditions were nearly identical, since no animals were into the stable. The air flow and air exchange were nearly completely caused by the outside wind. An example for outside wind measurements is shown in figure 2.

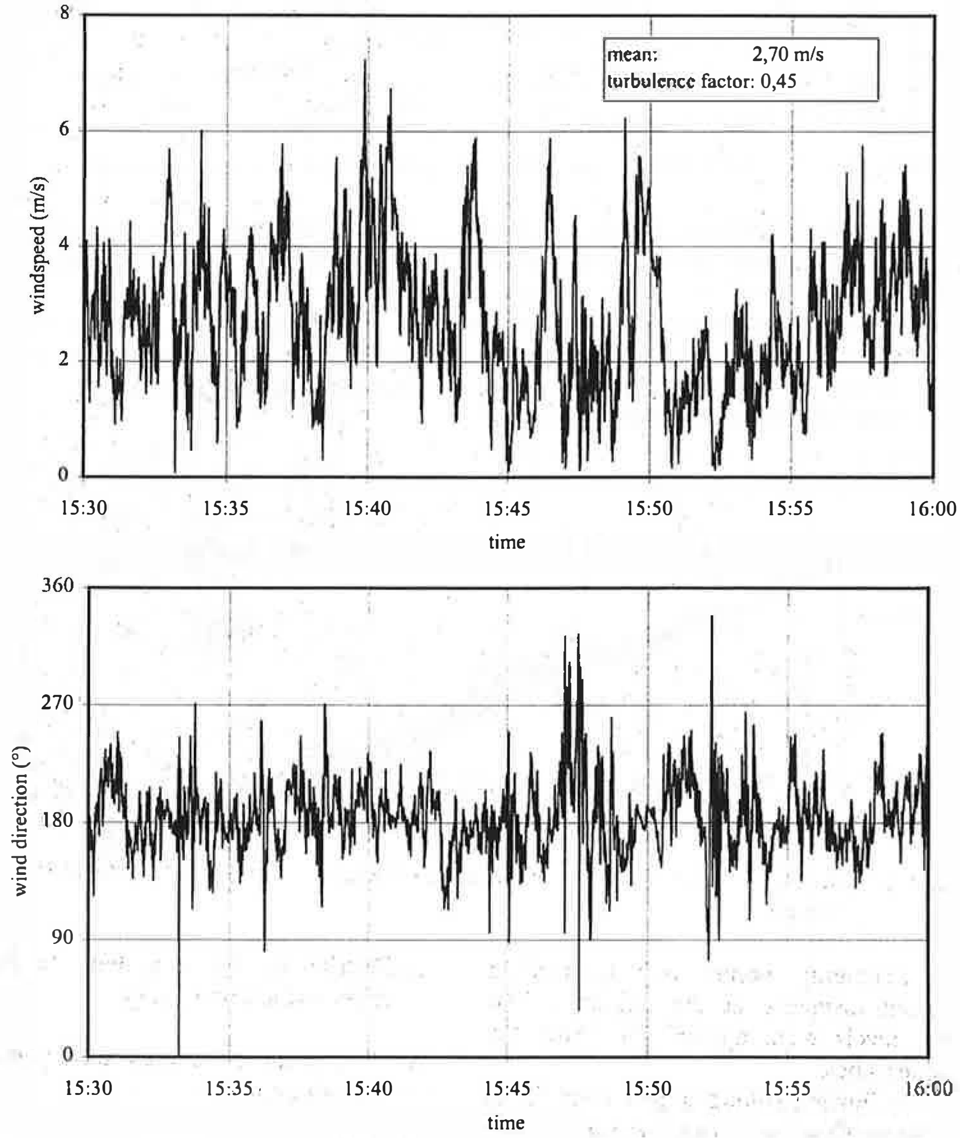

Figure 2 Outside wind measurements using an ultrasonic anemometer at 10 m hight, experimental livestock building, September 1997

The inside air flow of the building has been visualized, observed and sketched by the help of smoke tests (see Figure 3).

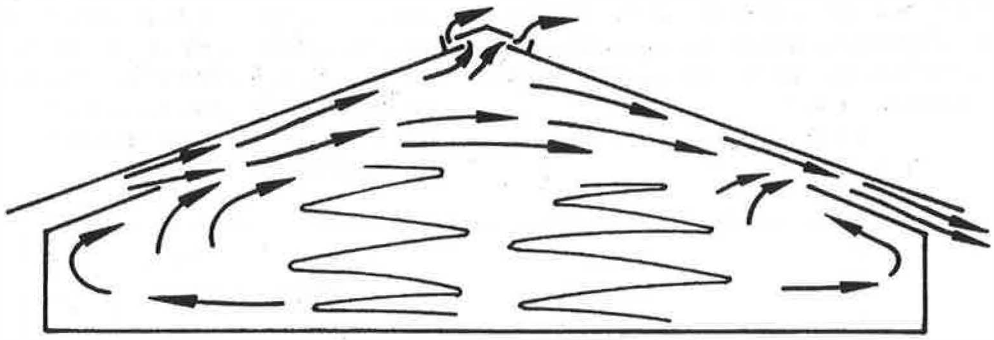

Figure 3 Draft of the air flow according to the visualization with help of smoke

Pressure differences, caused on the building by the outside wind lead to a flow through the livestock building. At the presented example this makes the left eaves opening to be an air inlet and both, the right eaves opening and the ridge openings work as an air outlet. Intensive air flow could be observed at the upper sampling level whereas the flow at animal height occurred to be very poor.

Figure 4 shows a decay curve obtained from a measurement using the tracer gas method with Krypton 85.

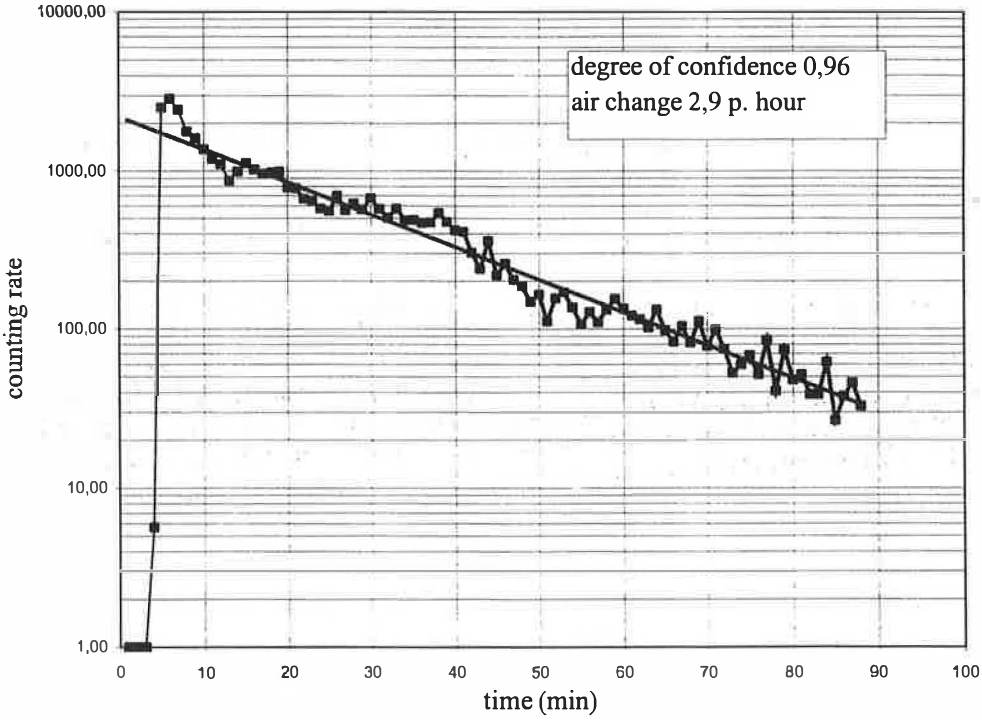

Figure 4 Example of a decay curve, experimental livestock building, tracer gas Krypton 85

The semilogarithmic plot above (Figure 4) gives a linear decay function. Fluctuations of the counting rates may be a result of the turbulent air flow in the measuring volume and of the statistic of the counting process on self.

Continuous addition of SF_6 leads to a concentration behaviour shown in Figure 5.

The low sampling rate of the SF_6 method (described above) results in a small number of measurement values and a poor time resolying capability. Calculating the air volume rate on the base of these measurements occures to be uncertain.

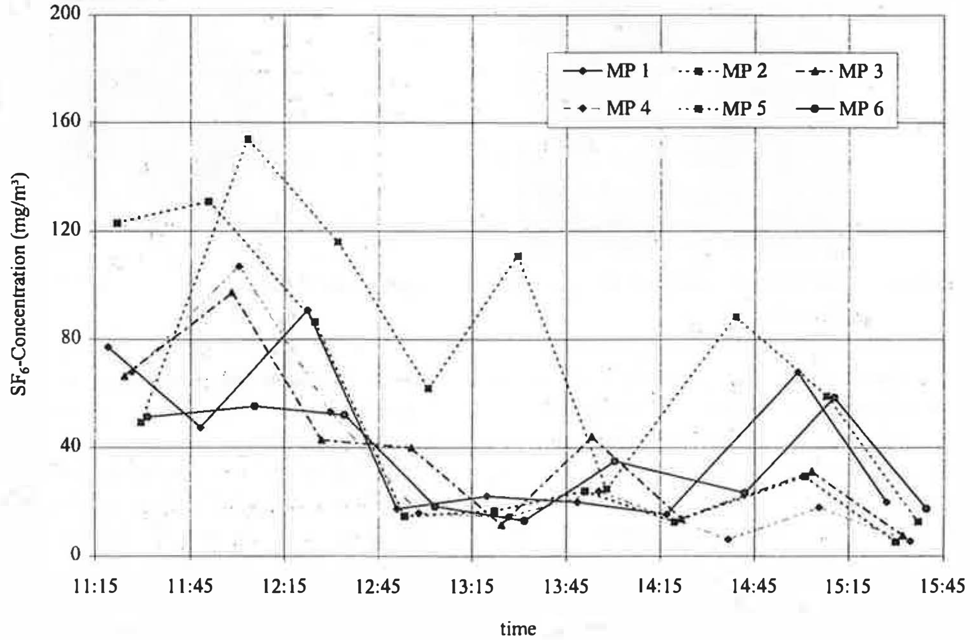

Figure 5 Example for the time related behaviour of the SF_6 concentration at the experimental livestock building, continuous addition of SF_6 to the inside air

Using the 40 sampling points of the Krypton method allows the locus-dependent presentation of the time dependent concentration change. Plotting the concentration change (i. e. change of counting rates) at it's sampling rate allows an insight to the process of the tracer gas distribution in the building. To present these plots would go beyond the scope of the present paper, but the air change rates of the 40 sampling points (see figure 6) can be seen as a representation of this data.

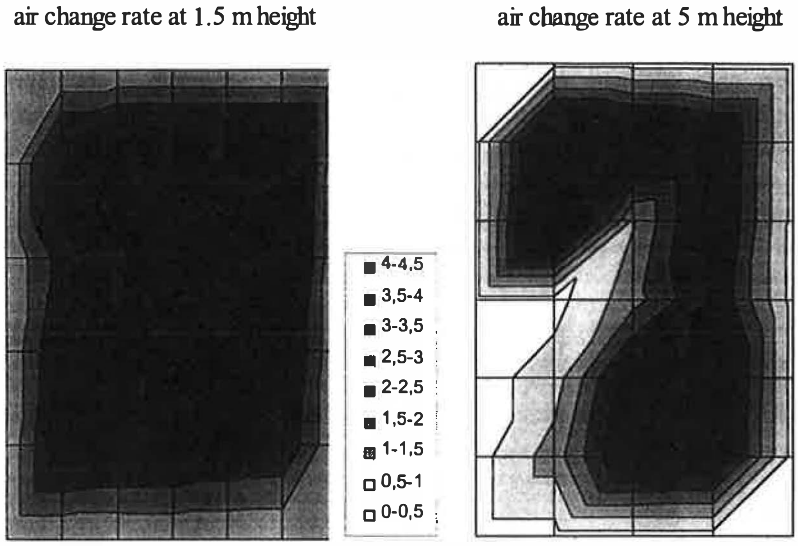

Figure 6 Air change rates of an experimental cattle house, calculated from Krypton 85 decay curves

The results indicate a non-uniform air flow through the building. Therefore it can be concluded, that a low number of sampling points (i. e. 6 points) in such an experiment yields to large measuring errors. The installation of 40 sampling points has been found to be a sufficient quantity to measure even in buildings with natural ventilation. Assessment and comparison are becoming possible with this method for systems with regard to their ventilation capacity.

Together with the recorded concentrations statements concerning the emissions derived from diverse animal species or keeping systems are also practicable.

DISCUSSION

The assessment of ventilation system for livestock buildiings regarding to interior clima and emissions needs knowledge about the air rate of the building. It is generally difficult to determine the air rate, especially in thouse buildings with natural ventilation. Tracer gas techniques are used by the ATB. SF_6 and Krypton 85 have been used for measurements in an experimental cattle house. The outcome of the investigations for SF_6 measured by using a gas monitor shows that in buildings without ideal mixing between interieur air and ambiente air strong uncertainties reasoned by poor local and time resolving power. More reliable is the 40 sampling point measurement set with Krypton 85 as a tracer gas. Concentration changes can be monitored and displayed locally resolved at a sampling rate of 1 second which provides an insight into the spreading process insight of natural ventilated livestock buildings. The 40 sampling points supply a sufficient database to get save results by determining the air rate.