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A METHOD FOR FIELD MEASUREMENTS OF VENTILATION RATES WITH CO_2-INDICATOR TUBES

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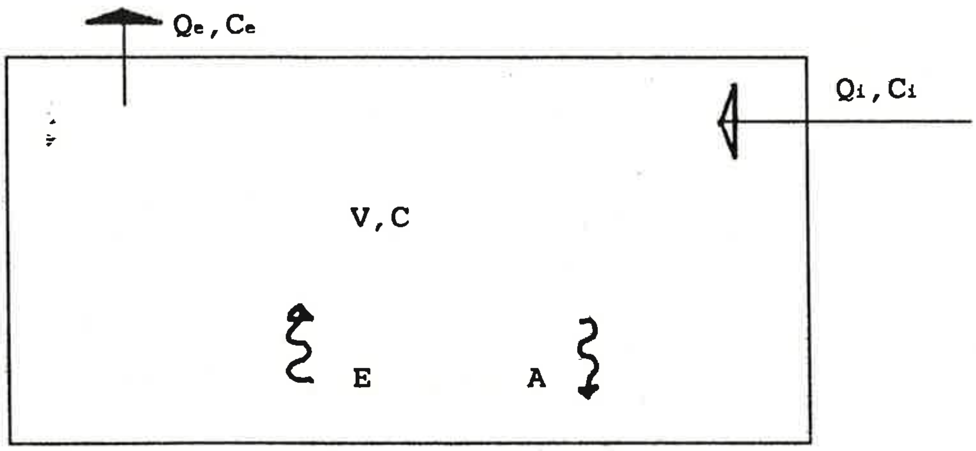
ABSTRACT

A new method for field measurements for ventilation rates has been developed. It is based on the decay method with carbon dioxide (CO_2) as the tracer gas. The concentration of CO_2 is measured with indicator tubes. The method is applicable to air exchange measurements in dwellings and offices, and the ventilation rates may vary from 0.1 1/h to 3 1/h with an inaccuracy of less than 20%. The duration of the measurement varies from 2 to 3.5 hours depending on the air exchange rate. Other sources of CO_2 must not be present in the room during the decay. The method is especially suitable for single room measurements.

INTRODUCTION

The aim of this study was to develope a cheap and simple method for air exchange measurements. Carbon dioxide was chosen as the tracer gas and the CO_2 concentration was measured with indicator tubes. Indicator tubes were chosen because they require no special skills and are relatively cheap.



V=volume of the chamber, C=concentration at moment t
Q_i=inlet air flow, C_i=concentration of inlet air
Q_e=exhaust air flow, C_e=concentration of exhaust air
E=emission of the tracer gas
A=adsorption of the tracer gas

Fig. 1: Single zone model

This measurement method is based on a single zone model, which is described in Fig.1. The concentration of the tracer gas is assumed to be uniform when mixing fans are used during the injection of CO_2. Our previous experiences support this assumption [1]. The following equilibrium can be written

$$V(C+dC) = Q_i C_i dt + Edt - A - Q_e C_e dt + VC . \qquad (1)$$

Assuming that $Q_e = Q_i$ and $C_e = C$, we can write

$$VdC = Q_e(C_i + E/Q_e - C)dt . \qquad (2)$$

Using the notation

$$C_E = E/Q_i , \qquad (3)$$

which gives the change in concentration due to constant emission in a stationary situation, we get

$$\int_{C_0}^{C} \frac{dC}{C_i + C_E - C} = \frac{Q_e}{V} \int_{t_0}^{t} dt . \qquad (4)$$

On the other hand Q_e/V = n (air exchange rate), so after integration Eqn. 4 becomes

$$n = \frac{1}{t - t_0} \ln \frac{C_0 - C_i - C_E}{C - C_i - C_E} . \qquad (5)$$

Plotting time versus concentration on a logarithmic scale we can detemine the air exchange rate from the slope of the decay lines.

MEASUREMENTS

Eight laboratory tests were made in a test chamber to test the applicability of carbon dioxide indicator tubes in ideal conditions. The results were compared with the air exchange rate measured simultaneously with multichannel measurement equipment using R12 as tracer gas. Comparison was also made with a CO_2-infrared-gas analyzer. Field measurements were made in dwellings to estimate the reliability of the method. The results of the experiments are shown in figures 2 and 3.

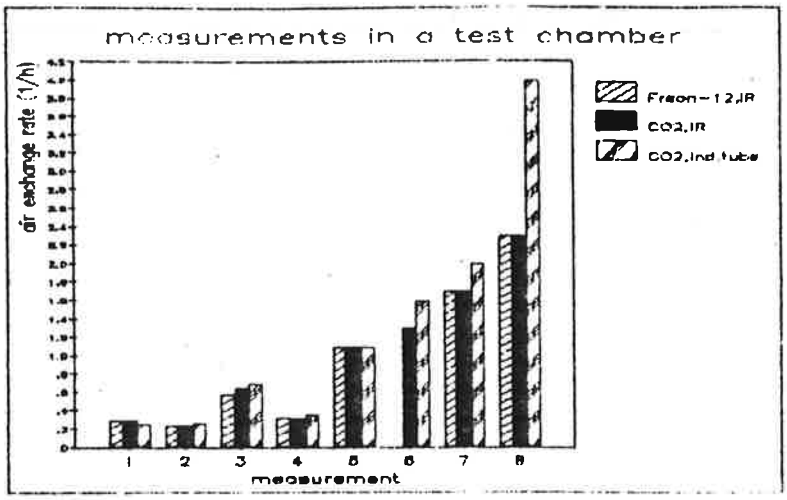


Fig. 2: Measurements in a test chamber

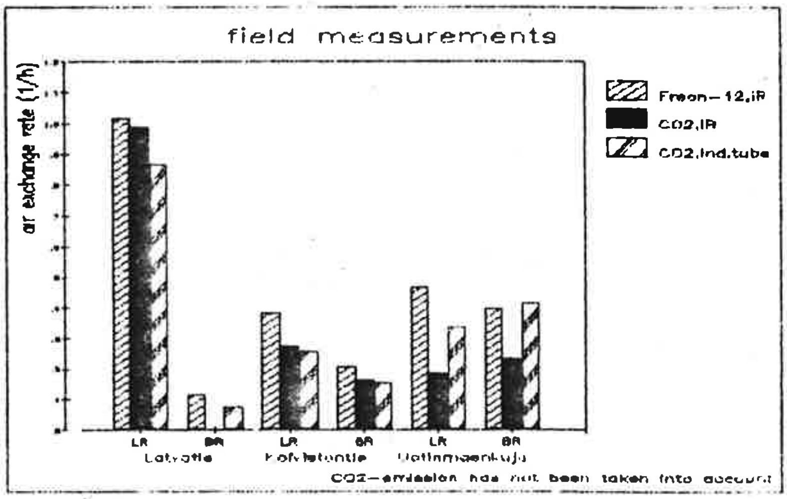


Fig. 3: Field measurements

DESCRIPTION OF THE AIR EXCHANGE MEASUREMENT PROCEDURE

The measurement procedure was developed from laboratory tests. Different initiation concentrations were tested and 2000-2500 ppm was found to be suitable; lower concentrations increase the measurement error. The duration of the measurement, from 1 to 2.5 hours, was also determined from laboratory measurements. The number of samples was optimized according to reliability and costs.

In the following the air exchange measurement procedure is described step by step.

Step 1: Injection of tracer: Carbon dioxide is spread from a gas bottle and mixed with 1-2 fans. The amount of CO_2 in litres should be 2.5 times the volume of the building in cubic-metres. The amount of tracer can be measured with eg. a flow meter. The duration of the injection varies from 20 to 40 minutes. The mixing fans are disconnected 10 to 20 minutes after the injection has ceased.

Note: Apart from the measurer there must be no other sources of carbon dioxide present during the decay time.

Step 2: Measurement of concentration: The background concentration is determined by one sample or estimated. The first sample is taken about 10 minutes after the disconnection of the mixing fans. Second sample is taken 30 minutes after the first sample. The air exchange rate is estimated from the first two samples. The third and fourth samples are taken at the following intervals from the second sample
-if n<0,5 1/h, then samples are taken at interval of 1 hour
-if 0,5 1/h<n<1,5 1/h, then the interval is 30 minutes
-if n>1,5, then the interval is 15 minutes.

Step 3: Determination of air exchange rate: The background concentration is extracted from the samples. The concentration on a logarithmic scale is plotted versus time. The air exchange rate can be determined by finding the slope of the decay lines. This can be done either by regression analysis (eg. least square sum) or graphically.

CONCLUSIONS

Tests in a laboratory test chamber showed that carbon dioxide can be used as tracer gas in ideal conditions. The differences between R12-reference measurement and CO_2-IR-measurement were 0-10%. In test room conditions there were 10-20% differences between indicator tube measurements and the reference.

Field measurements with indicator tubes in rooms with neglible CO_2-emission showed a measurement inaccuracy 20% higher than the reference. The influence of the measurer is included. The inaccuracy increases remarkably if there are other sources of CO_2 present during the decay time. The initiation concentration of the tracer was found to be close to uniform if all the doors were open and mixing fans were used during the injection. Allowing for human CO_2-emission was found to be too complex to be included in a simple measurement method.

REFERENCES

1. Roos, R., Majanen, A., Helenius, T., Ilmanvaihdon hyötysuhteen mittaaminen eri ilmanvaihtojärjestelmissä. 1985. Sisäilmastoprojekti, Teknillinen Korkeakoulu, LVI-laboratorio, Raportti C:18