The Use of Detector Tubes with Carbon Dioxide as a Tracer Gas

M. Sandberg and J. Sundberg
The National Swedish Institute for Building Research

Introduction

Tracer gas concentrations are often analysed by using infra-red spectroscopy. Infra-red gas analysers have a fast response time and are accurate. However, this type of instrumentation is relatively expensive and can only be used for this type of measurement. A cheaper alternative is therefore preferred.

Normally there is a trade-off between cost and accuracy. Detector tubes are inexpensive and are available for many gases, among them CO_2. They are packed with a selective solid absorbent which gives a colour reaction with the gas in question. The higher the concentration of gas which enters the tube the further the coloured region extends down the packing. The tubes have approximate calibration markings which show the concentration of the gas.

This article reports a method of measuring the ventilation air flow rate using a tracer decay technique in occupied houses with CO_2 as a tracer gas. The metabolic CO_2 from people is taken into account. The accuracy of the method has been explored through various tests.

Theory

Consider a room with complete mixing of both the outdoor air supplied, q, and the tracer gas released in the room. The equation of continuity gives the following well known expression for the tracer gas concentration C(t) in a room with volume V:

$$V\,dC(t)/dt = -q[C(t) - C_b] + m(t) \qquad (1)$$

where C_b = background concentration

t = time

m = production rate of CO_2 from people

It is assumed that q is time-independent and, after integrating equation (1) from 0 to T_m (the total measuring period), the following is obtained

$$q = V[C(0) - C(T_m) + \int_0^{T_m} \frac{m(t)}{V}\,dt]/(\int_0^{T_m} (C(t) - C_b)\,dt) \qquad (2)$$

If it is assumed that the production rate of CO_2 from people is constant, then equation (2) may be written as

$$q = V[C(0) - C(T_m) + \frac{mT_m}{V}]/(\int_0^{T_m} (C(t) - C_b)\,dt) \qquad (3)$$

If n samples of the concentration are taken with the same period, Δt, between each sample, then the integral in (3) can be calculated as

$$\int_0^{T_m} (C(t) - C_b)\,dt = 0.5(C_1 + C_n)\Delta t + \sum_{i=2}^{n-1} C_i \Delta t \qquad (4)$$

Measurements

All the tests reported in this article were carried out in an indoor test house (volume 175.7 m3) (see references 1 and 2). During all the tests the house was ventilated by a mechanical extract system. The air was extracted from the kitchen and bathroom and the intake of air was through openings in the living room and bedroom. The extract flow rates were measured to an accuracy of between 2–3% with orifice plates. The carbon dioxide concentrations were recorded both with detector tubes (manufactured by Dräger) and an infra-red gas analyser (manufactured by Leybold-Hereus, Binos type analyser). In each test the concentration was recorded in the living room. The tests were carried out at two flow rates. For each flow rate, tests were made with the house unoccupied and with one or two persons in the house. The tests started by releasing carbon dioxide to an initial concentration of about 2000 ppm and the number of samples, n, taken with the detector tubes amounting to about 5. During the whole measuring period small mixing fans were in operation.

Figure 1: CO_2 Dräger tube and sample bellows

Figure 2 shows an example of the concentrations recorded in one test. The dashed line represents the exponential decay of concentration which can be expected with no production of carbon dioxide and complete mixing. The decay is far from exponential and it is therefore not possible to utilize the slope of the decay curve to estimate the flow rate of air. Instead the flow rate, q, is determined by applying equations (3) and (4).

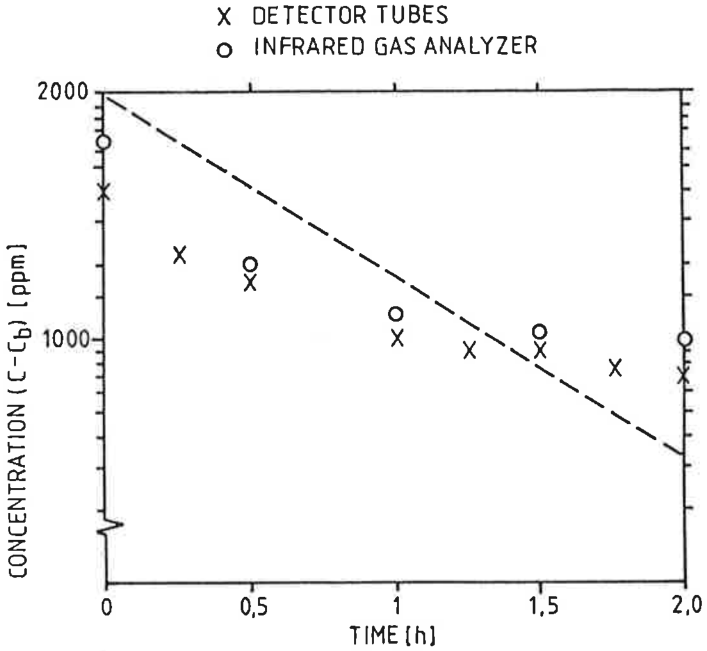

Figure 2: Examples of recorded concentrations

The results from all tests are compiled in Table 1. The flow rate is given as the specific flow rate expressed in house volumes per hour. The production rate of carbon dioxide was set to 0.35 litres per minute per person.

The accuracy of the method is quite high and the errors are of the same order of magnitude as the standard decay technique. In these tests an unfavourable location had been chosen for the sampling point, i.e. the living room. It would be better to sample in a room where the main part of the air leaves the house, which should give better accuracy.

	NOMINAL FLOW RATE (house volumes/h)	MEASURED FLOW RATE Infrared gas analyzer	Detector tubes
UNOCCUPIED	0.54	0.58±0.15 (17 %)	0.52 (-4 %)
	0.96	0.88 (-8 %)	0.79 (-17 %)
ONE PERSON IN THE LIVING ROOM	0.54	0.55 (2 %)	0.50 (-7 %)
	0.96	1.02 (+7 %)	0.87 (-8 %)
ONE PERSON IN THE SLEEPING ROOM	0.54	0.57 (+5 %)	0.51 (-5 %)
	0.96	1.02 (+7 %)	0.89 (6 %)
TWO PERSONS IN THE HOUSE	0.54	0.57 (+6 %)	0.44 (-18 %)
	0.96	1.22 (+27 %)	1.12 (+17 %)

Table 1: Results (the relative error of the measured flow rate is given in brackets)

Conclusions

By using the area under the decay curve it is possible, when the release rate of metabolic CO_2 from people is constant and known, to estimate the flow rate of outdoor air entering an unoccupied house.

References

1. Sandberg, M.
An indoor test house
Air Infiltration Review, Vol. 6 No. 1, November 1984.

2. Sandberg, M. and Blomqvist, C.
A quantitative estimate of the accuracy of tracer gas methods for the determination of the ventilation flow rate in buildings.
Building and Environment, Vol. 20 No. 3, 1985.

COMIS – A Joint Research Effort at the Lawrence Berkeley Laboratory

The Energy Performance of Buildings Group at Lawrence Berkeley Laboratory (LBL) is investigating the possibility of hosting a one-year joint reseach effort to develop a multizone infiltration model commencing October 1, 1988. The task for the workshop (Conjunction of Multizone Infiltration Specialists (COMIS)) would be to develop a detailed multizone infiltration program taking crack flow, HVAC-systems, single-sided ventilation and transport through large openings into account. Multigas tracer measurements and wind tunnel data would be used to validate the model. The agenda integrates all participants' contributions into a single model containing a large library of modules. The user-friendly, PC-based program would have different levels of support and would be aimed at building professionals.

This year-long effort would enable LBL to develop the model, perform the validation and produce a user handbook. They plan to invite interested colleagues to participate in this research effort. As the host, LBL would supply the work space, computer time and limited clerical support. Researchers participating in this workshop must receive complete financial support from their home institutions/countries. LBL feel that countries with infiltration/ventilation research ought to be in favour of this workshop, as this joint effort would supply an advanced program to all participating institutions at the cost of only one man-year each.

Interested researchers should contact LBL as soon as possible at the following address.

Helmut E. Feustel
Lawrence Berkeley Laboratory
Building 90, Room 3074
Berkeley
CA 94720, USA