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An Improved Multiple Tracer Gas Technique for the Calculation of Air Movement in Buildings

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Introduction

This paper describes a series of tests carried out in two interconnected environmental chambers, to determine the accuracy of airflows calculated from tracer gas measurements using a new rapid sampling system.

Sampling System

The schematic layout of the tracer gas sampling system is shown in Figure 1. Using two chromatographic separation columns in parallel and a portable gas chromatograph (Analytical Instruments Ltd., Model 505), it was possible to measure the concentration of Freon 12 (dichlorodifluoromethane) and Freon 114 (1,2 dichlorotetrofluoromethane) in air. The two 4-port valves were switched sequentially such that the column not in use was continuously flushed with argon. For the two tracer gases tested, a sampling interval of 30 seconds was used. This system was capable of measuring three tracer gases simultaneously, the third tracer gas being BCF (bromochlorodifluoromethane); this would extend the sampling interval to 45 seconds.

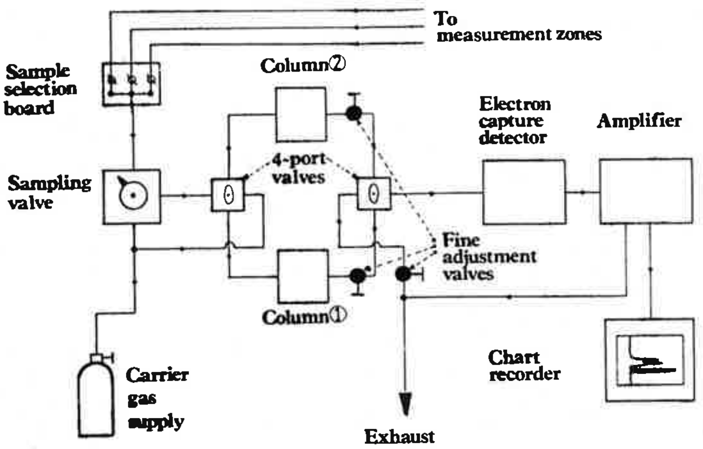

Figure 1. Sampling system

Test Procedure

The two environmental chambers used were 30m^3 in volume, each having a separate ducted supply and extract ventilation system. Air/tracer gas in both chambers was sampled at three levels, i.e. floor level, 1.5 m high and 2.4 m high (50 mm below ceiling).

Air movement between the two chambers took place through two 100 mm diameter holes in the partition wall, one 150 mm above floor level and the second 1 m above floor level. The supply air flow rate to both chambers was set to provide a steady airflow through the low level opening from chamber 2 to chamber 1. A ducted low speed fan on the other opening induced air movement from chamber 1 to chamber 2. Air velocites in the supply ductwork were measured using a pitot tube and inclined-tube manometer. The air velocities through both openings in the partition wall were measured using a hot wire anemometer. The tracer gases were injected manually and mixed using desk fans.

Test Results and Analysis

Initially, a single chamber ventilation rate measurement was taken to observe any significant differences between measured gas concentration for the two columns used (Test 1). Figure 2 shows the exponential decay of tracer gas concentration.

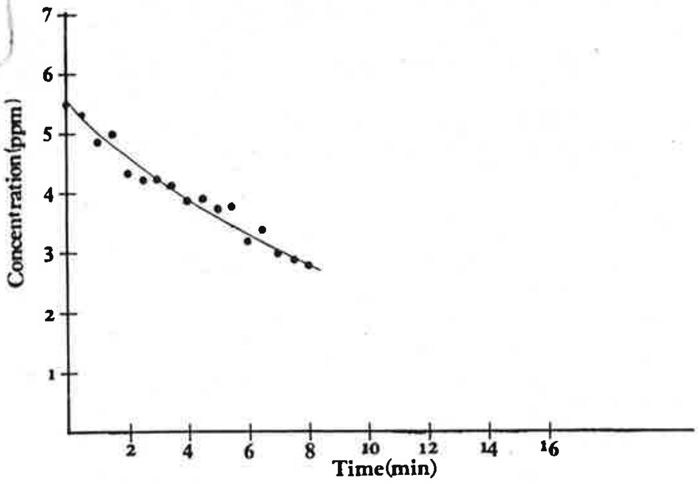

Figure 2. Tracer gas concentration decay in single space

The time taken for Freon 12 to mix with air in a single chamber without the aid of mechanical mixing (Test 2) is shown in Figure 3. A pulse of tracer gas was released at floor level and allowed to disperse. The tracer gas concentration tended to equilibrium after approximately 10 minutes

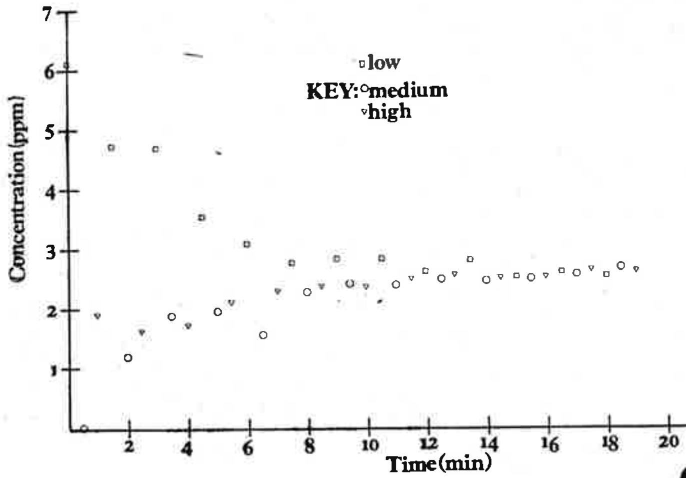

Figure 3. Tracer gas (R12) concentration in chamber 1 – no mixing.

A one-directional airflow was induced from chamber 2 to 1 by switching off the supply air system to chamber 1 (Test 3). Freon 12 was released in chamber 2, mixed, and the growth

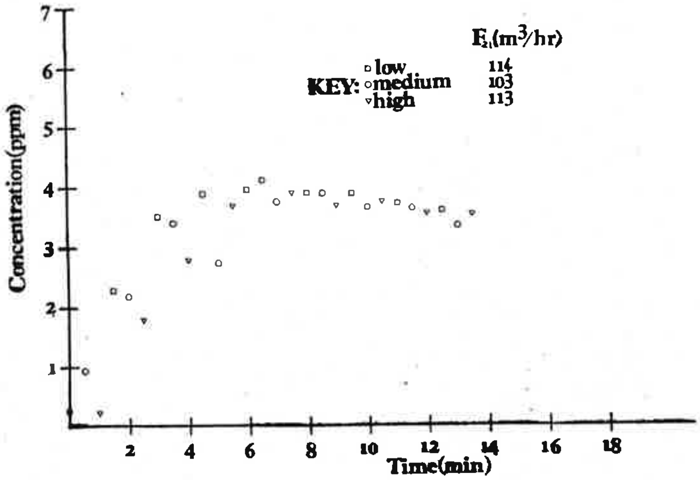

Figure 4. Growth of tracer gas (R12) concentration in chamber 1

of tracer concentration monitored at the three different levels in chamber 1. Figure 4 shows the three growth curves obtained; the three estimates of air movement suggest non-uniform mixing errors of approximately ±7%.

Table 1 summarises the air movement data obtained in subsequent tests using two tracer gases. Tests 4 to 5 are the result of a one-directional airflow from chamber 2 to chamber 1. The errors found between calculated and measured airflows were 2.3% and 5.5% respectively. Supply air inputs measured using a pitot tube and those calculated from tracer gas measurement show reasonable agreement; the error lies between 5% and 10%.

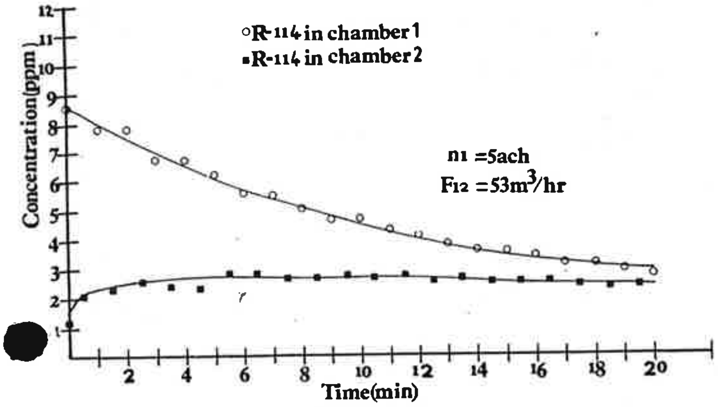

Figure 5. Concentration of tracer gas (R114) in both chambers with a two-directional airflow

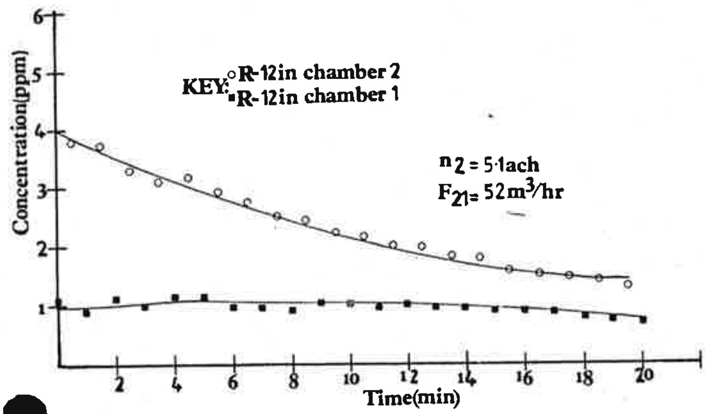

Figure 6. Concentration of tracer gas (R12) in both chambers with a two-directional airflow

Tests 6 to 8 inclusive were with two-directional air movement between the chambers. Figure 5 and 6 show the tracer gas concentration time points obtained during Test 6. The error found between calculated and measured airflows lies between 0% and 8%. Supply air inputs to both chambers measured directly and from tracer measurements again show reasonable agreement, with an error of between 4% and 10%.

Discussion

The magnitude of the two-directional airflows was calculated using a one-directional approximation to give 'first order' estimates.[1]

Where two-directional air movement exists between two connected spaces, recirculation of tracer gas will occur. Consequently the shape of the tracer decay curve in the source room will not be a simple exponential function. The error associated with ignoring recirculation of tracer gas is a complex function of time, air change rate and intercell air movement.[2]

Generally the slope of the tracer decay curve in the source room for time from 0–10 minutes closely approximates to a single exponential function. After this period, the fact that the decay curves represent the sum of two exponential functions becomes increasingly significant.

Provided a sufficient number of concentration and time points are available i.e. at least ten, then a good estimate of the source room air change rate is obtained using the 'first order' estimations. The growths of tracer concentration in the receiving rooms are less strongly dependent on time, so that sufficiently accurate estimations of air flow can be obtained using this method over a period of up to 30 minutes.

References

1. S.J. I'Anson, C. Irwin and A.T. Howarth
   Air flow measurement using three tracer gases.
   Building and Environment, Vol. 17, No. 4, pps245–252, 1982.
2. C. Irwin, R.E. Edwards and A.T. Howarth
   The measurement of airflows using a rapid response multiple tracer gas technique
   To be published

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Table 1. Summary of Results

Test No.	Calc. Supply Rate (1) m³/hr	Calc. Supply Rate (2) m³/hr	Measured Supply Rate (1) m³/hr	Measured Supply Rate (2) m³/hr	Calc. Airflow (1)–(2) m³/hr	Calc. Airflow (2)–(1) m³/hr	Measured Airflow (2)–(1) m³/hr	Measured Airflow (2)–(1) m³/hr	% Error Measured (1)–(2) Calc.	% Error Measured (2)–(1) Calc.
1		See Figure 2								
2		See Figure 3								
3		See Figure 4								
4	110	116	105	127	–	43	–	44	–	2.3
5	50	180	55	170	–	127	–	134	–	5.5
6	98	100	90	110	53	52	52	54	2.0	3.9
7	111	119	120	108	31	49	31	47	0	4.1
8	57	53	60	55	51	26	53	24	3.9	7.6