Development of a Multi-Tracer Gas Technique for Observing Air Movement in Buildings

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Introduction

A method for following air movement within buildings, which uses several different tracer gases simultaneously, has been developed. The method consists of the following sequence of operations:

- up to four tracer gases are released at various points within the building.
- the mixture of gases is sampled at any number of positions in the building as a function of time since the release.
- the samples are chemically analysed to produce curves showing the concentrations of each gas stepping through time and space.
- the variations in gas concentrations are used to evaluate air movement through the space. Specific experiments to illustrate such air movement have been carried out and these are summarised below.

Tracer Gases and their Release

An extensive survey was carried out to find non-toxic, odourless tracers with a zero background concentration. It was also necessary to find unreactive chemicals whose concentrations were easily measured, and which could be readily separated for analysis. A series of perfluoro hexanes and decalins fit the requirements and the following ones have been used in the prototype development:

- PP1 perfluoro n-hexane
- PP2 perfluoro methyl cyclohexane
- PP3 perfluoro dimethyl cyclohexane
- PP5 perfluoro decalin

These compounds are low boiling liquids which makes for easy transport. They are currently injected into a space (remotely or manually) by evaporating about 1 ml using an electric heater. In some cases the gas is mixed with a desk fan.

Sampling and Analysis

Mixtures of room air and one or more tracers are sampled by drawing a small fixed volume of air (about 100 mls) through sample tubes packed with an adsorbent. Figure 1 illustrates the system for two sample points. Each sample point (Plate 2) consists of five removable stainless steel tubes packed with an adsorbent (chromosorb 102). At the front end of each tube a push cap fitting connects it to a solenoid valve which controls the exposure of the tube to the atmosphere. The pump, flow meter, pressure gauge, needle valve, three port solenoid valve and T piece are housed on a small trolley (Plate 1). Also included is the control system which opens and closes the solenoid valves. The valves are operated so that the tubes are exposed in pairs, one at each sample point. Samples are thus taken simultaneously at each point and in a timed sequence from 1 to 5. The sample tubes are capped for transportation to the automatic thermal desorber (Plate 3) where up to 50 tubes may be desorbed.

The tracer gases are desorbed from the sample tubes using a Perkin-Elmer Sigma 3B gas chromatograph fitted with a 4 m glass column packed with 5% SE30 on CHROM W.H.P. and a flame ionization detector (Plate 4).

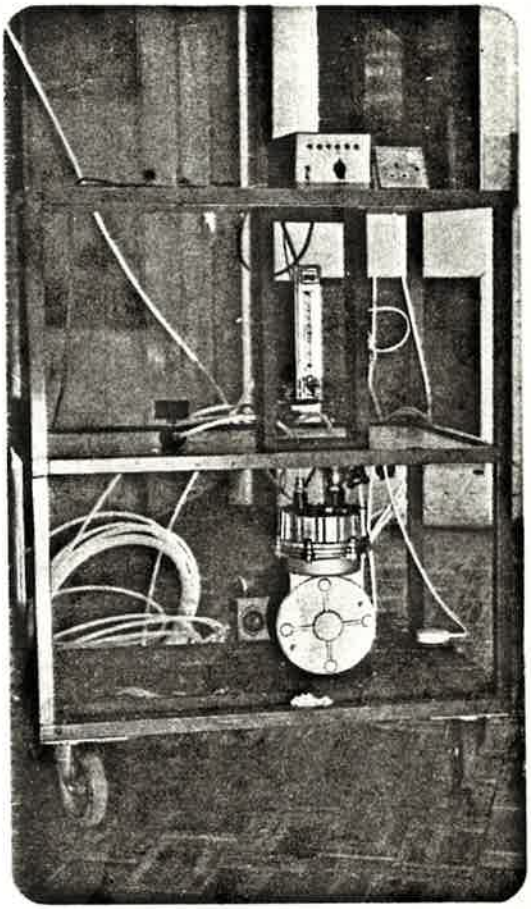

Plate 1. Pump and controller

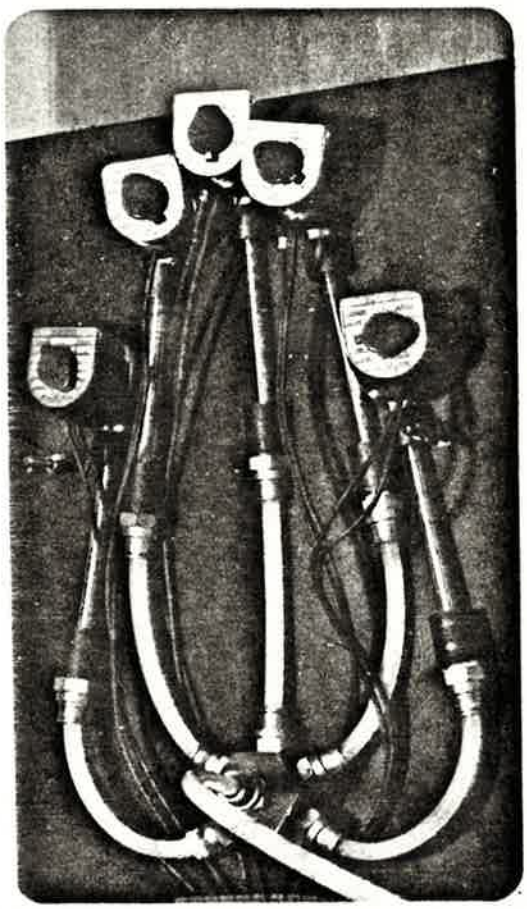

Plate 2. One sample point

Results

Figure 2 illustrates the variation in concentration of one tracer (PP1) up to 5 hours after its release into the sealed room. Between hours 1 and 5 the mean concentration in the room air at the two sampling points falls from 5.7×10^{-5}g/l to 5.0×10^{-5}g/l. The small drift downwards is probably due to residual infiltration occuring in the room, even though it was carefully sealed. A log linear plot of the data in Figure 2 implies a rate of only 1.7×10^{-2} air changes per hour.

Similar tests were carried out with the other tracer gases and the air change rate obtained by averaging all the results for this five hourly period was $(1.7 \pm 0.3) \times 10^{-2} h^{-1}$.

The conclusion is that the gases are not adsorbed by walls and furnishings.

Tests for Stratification

Method

Sampling point A was 2.89 m above the floor, and point B 1.36 m. The ceiling to floor height was 2.95 m. 30 minutes after the tracers were released, sampling commenced at 30 minute intervals. In one test a desk fan was left on to mix the room air, and in a second test the fan was not used.

Results showed that no significant stratification occured in a 2½ hour period.

Experiment To Show Air Movement Between Two Zones Using Two Tracer Gases

Two sampling points were set up, one in the sealed room used in the previous tests and one in the corridor outside the room.

Two tracers were released, one in each zone. Air in each zone was mixed, with the communicating door closed. Samples were taken before opening the door, and at 5 minute intervals after it was opened. Figure 3 shows some of the results. PP1 (full line) is released in the sealed room, and after mixing reaches a concentration of 4.60×10^{-5}g/l (roughly 4 ppm). Its concentration in the corridor is very small (less than 0.2×10^{-5}g/l). PP3 is released in the corridor and after mixing reaches a concentration of 2.35×10^{-5}g/l. Its concentration in the room is zero.

When the door is opened, PP1 is swept into the corridor – leading to a fall in room PP1 and a rise in corridor PP1. Similarly, PP3 is swept into the room, with a concomitant fall in the PP3 concentration in the corridor.

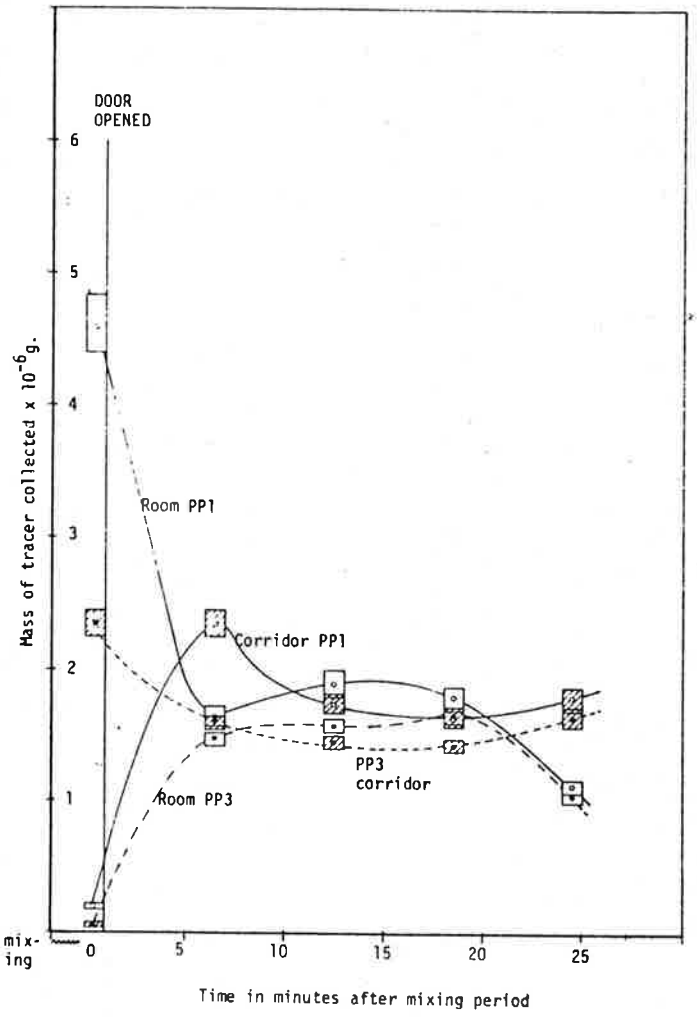

Figure 3. Typical curves for a two-zone, two-tracer test

Forthcoming Conferences

1. Second International Congress on Building Energy Management
   Ames, Iowa, USA
   May 31 – June 3 1983

   Further information from:

   Office of the Secretariat
   c/o Prof. James E. Wood
   Iowa State University
   102 Scheman Building
   Ames
   Iowa 50011
   USA

2. ASHRAE Semi-Annual Meeting
   Washington DC, USA
   June 26 – 30 1983

   Will include a symposium entitled 'Air infiltration model validation'

   Further information from:

   R.S. Burkowsky
   ASHRAE
   1791 Tullie Circle N.E.
   Atlanta
   GA 30329
   USA

3. PLEA '83
   International Conference on Passive and Low Energy Architecture
   Crete, Greece
   June 28 – July 5 1983

   Will include case studies on retrofits and research and development in ventilation, modelling and simulation

   Further information from:

   PLEA '83
   Architectural Association Graduate School
   36 Bedford Square
   London, WC1B 3ES
   Great Britain

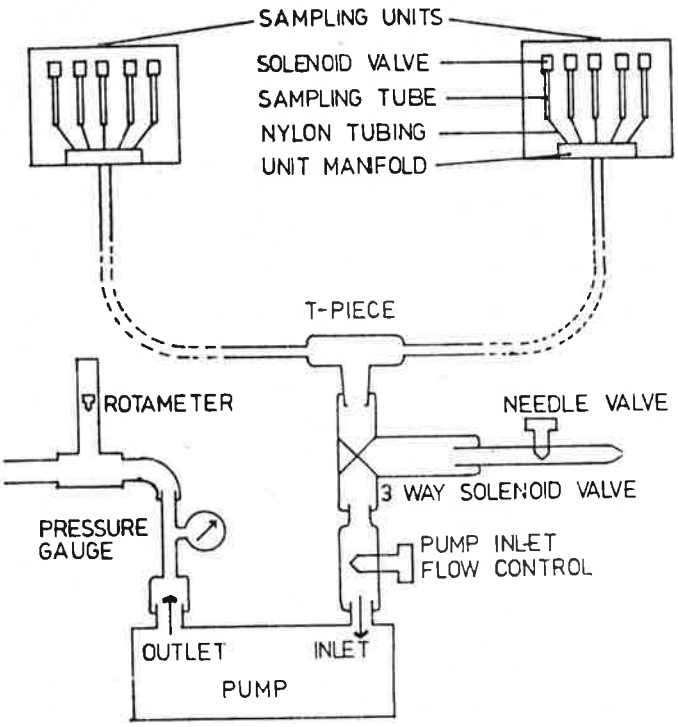

Figure 1. The sampling system

Plate 3. Automatic thermal desorber

Plate 4. Gas chromatograph

Demonstration of the Technique

Tests for Absorption into Walls and Furnishings

Method

An office of volume 33 m³ with a false panelled wall, carpeted concrete floor, concrete ceiling and large sliding double glazed windows was sealed with tape over joints in the wall, gaps in the ceiling, the window frame and the skirting board.

The tracer release system was set up in the middle of the room with an oscillating fan to ensure good mixing. 1 ml of each tracer was evaporated in the room and the door sealed from the outside with the fan switched on. After 27 minutes the fan was switched off. After another 3 minutes the first sample was taken. A further four samples were taken at intervals of 30 minutes. The test was repeated using intervals of one hour (Figure 2) and intervals of one minute between samples.

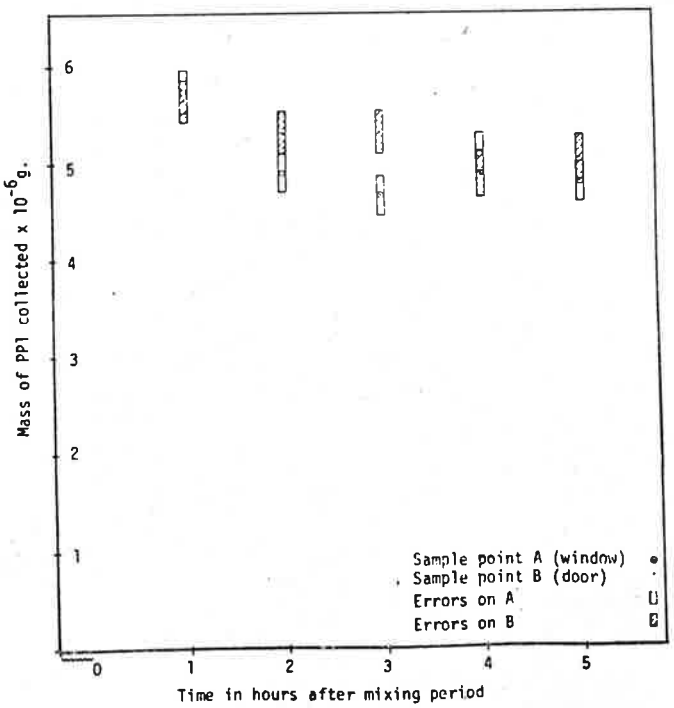

Figure 2. Room surface absorption test with PP1