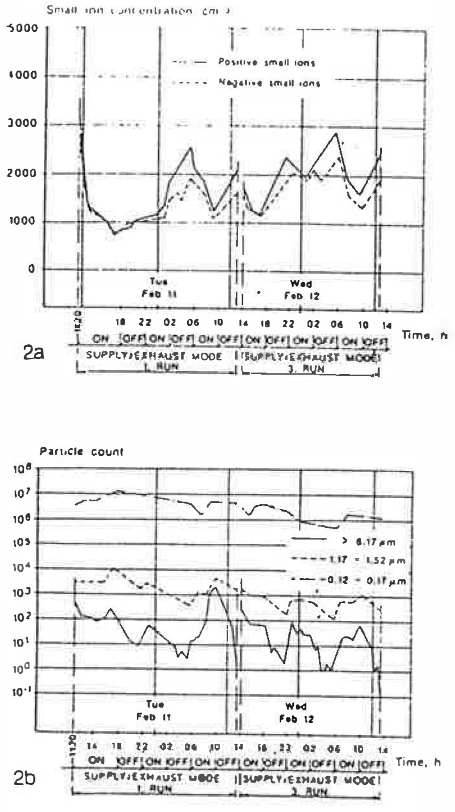

Fig. 2. Small-ion concentrations (2a) and particle counts (2b) measured when the test room was ventilated in the supply/exhaust mode.

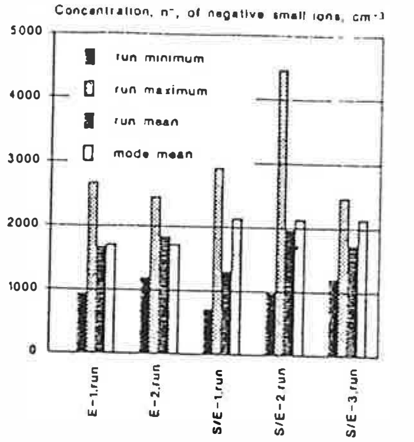

Fig. 3. Concentration, n⁻, of negative small ions measured in the test room for different runs in the exhaust (E) and supply/exhaust (S/E) ventilation modes.

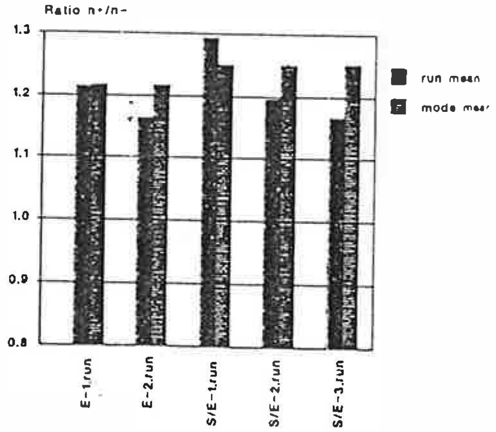

Fig. 4. Ratio, n+/n⁻, of the concentrations of positive to negative small ions measured in the test room for different runs in the exhaust (E) and supply/exhaust (S/E) ventilation modes.

LABORATORY SIMULATION OF HUMAN BIOEFFLUENTS SOURCES USING CARBON DIOXIDE AS A TRACER GAS

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ABSTRACT

An experimental setup is presented that can measure concentrations generated around a pulsating source of carbon dioxide (CO_2) that simulates human respiration. The experimental setup is used to study the relationship between the ventilation efficiency and the pollutant removal efficiency of a space. These are two key parameters which describe the ability of a space in providing a comfortable and healthy environment for its occupants. Preliminary results obtained so far have focused on the conditions inside a small test chamber. Some preliminary results are presented after a discussion on current tracer gas techniques used in the field.

INTRODUCTION

Current tracer gas methods fail to quantify the ventilation efficiency (VE) of an office space in real conditions of occupancy (1). This is a failure due to two major limitations involved in any field measurement technique: the scale of the testing site and the time required for testing. To deal with the different sizes of buildings, two types of indices are currently available but are not related to each other yet. There are local indices that can evaluate the ability of ventilation to dilute a source at a worksite and there are global indices that can describe the overall mixing of the room where the worksite is located. Transient methods that incorporate a time variable to account for building ventilation schedules, occupancy or pollutant sources are still at the experimental or modelisation stage.

During the thermal comfort studies of the 70's similar limitations were encountered when an index was sought to rate the indoor thermal environment for human occupancy. One index, the Predicted Mean Vote index, was eventually incorporated into a portable instrument that simulated the heat transfer between a sedentary human being and its immediate surroundings (2). Based on assumptions and equations concerning human heat transfer mechanisms, it was able to guess how a person felt thermally and register a vote. Because of its ease of use and because it could be left in a space for several days, this instrument provided a reliable tool to assess a thermal environment without perturbing normal activities or influencing the way a building is operated.

This presentation describes how a similar instrument can be developed for the evaluation of the indoor air environment in office buildings. Before the method and some preliminary results are described, we will review some of the existing research that deal with air movements in buildings.

LITERATURE REVIEW

During the renaissance Leonardo Da Vinci was fascinated by the observation of the patterns created by moving water. In reviewing his notes, one comes across two small drawings showing a simple experiment he performed in a channel. A paddle, that he called a mobile, was lowered into the stream at two different heights In one case, the water is shown smooth and laminar while, in a second case, the water is disturbed and turbulent. He concluded that the movement and therefore the disturbance in the water was proportional to the movement of the mobile. Da Vinci was concerned with these problems while developing the plans for various waterworks projects.

Today, researchers use tracer gas techniques as a mobile to determine the movement of air in buildings. These tests are performed to assess the quality of the mixing of a space to verify if the ventilation is able to dilute and evacuate indoor pollutants. By injecting a gas in the air, the air movements can be traced for quantification and the air flow patterns can be qualified. Over time, if air travels correctly within an office, pollutants and fresh air will be carried along the stream forces imposed by the ventilation at a rate sufficient to satisfy comfort and health in the breathing zone of a worker. Unlike water in a channel however, the immediate effect of building ventilation over a source is difficult to observe visually because the process is fast and it varies constantly. To be able to see this process accurately, experiments must be repeated at a rate close to the rate of change of the air in the room and the rate of change of the events occurring in an office.

Since this is not practical, existing methods for measuring pollutant removal and VE use averaging techniques to reduce the need to sample frequently. The air change rate of a space can be measured by using the average decay rate of a gas over a period of a few hours (3). When observing a graph of the concentration changes versus time, the results will show a smooth exponential curve with a constant slope. Some methods, such as the mean age of air, use the area under the decay curve to quantify VE (4). Other techniques involve the injection of a tracer to simulate a pollutant and express efficiency by comparing the average concentration measured and the average rate of injection of the pollutant (5,6).

TEST CHAMBER AND DATA COLLECTION

A schematic of the test chamber and part of the data collection equipment is shown in Figure 1.

Tests are conducted in 64 m³ room that has its independent ventilation system. The supply fan of the system is linked to a controller that can vary the speed of the motor and provide between -100 and 200 L/s of air. The controller can be activated by a relay to simulate on-off cycles and, the controller can be set to ramp (reach maximum speed) in different time periods. A return fan completes the 'H' type of design that allows variation of the evacuation, return and fresh air flow rates.

Presently, the room simulates an interior zone, unoccupied, equipped with four fluorescent lamp fixtures (320W) and the exterior surfaces of the room are maintained at constant temperature. These conditions can be changed to simulate different scenarios typical of an interior zone of a building with one or two occupants. The room is equipped with two separate injection lines for CO_2 and sulphur hexafluoride (SF_6).

The CO_2 line (see Figure 2) can be used to deliver pure CO_2 or a gas mixture of air and CO_2 at 740 ppm. Injection is performed at a height of 0.6 m in the center of the room to simulate a seated person. All the volumes of gas are measured and adjusted using a rotameter or a precision bubble flowmeter. The solenoid valve at the end of line is activated by a relay controled by a timer to create pulses at intervals and durations between one second and 24 hours. CO_2 data are collected in the center of the room by a direct reading instrument with a passive infra-red detector. The detector has a precision of 50 ppm for readings up to 2000 ppm and of 100 ppm for higher readings. Concentrations can be obtained every 8 seconds and can be transferred to a computer for data analysis.

The SF_6 line sends pure SF_6 at the fresh air intake of the supply fan. This line is also activated by a relay and controled by a timer. SF_6 data are collected using a portable photoacoustic gas detector and samples can be collected at twelve different locations in the room. The shortest sampling rate is approximately 40 seconds and the detection limit is 0.05 ppm. Depending on the number of locations required for sampling, different sampling points can be selected using a twelve way valve activated by a relay and controled by a timer.

Air volumes going into the room can be measured in three different ways. A pressure grid located in the main duct of the ventilation system provides a pressure reading proportional to the airflow across the grid and this is measured with a pressure gauge. The ventilation airflow can be measured at either one of the three diffusers in the room using a balometer. Finally, air changes per hour can be measured using an SF_6 tracer gas decay.

PRELIMINARY EXPERIMENTS AND RESULTS

Preliminary testing was performed to find the correct injection method to obtain a good response from the CO_2 monitor at ventilation rates typical of infiltration in an office building. Results in Figure 3 show measurements of two series of CO_2 pulses labeled as pulses P1 and P2. Both have a duration of 2 minutes and were reproduced at 20 minute intervals. The average rate of injection was set to 0.3 Lpm for P1 (close to human respiration rate) and to 0.1 Lpm for pulse P2. For both pulses, the injection rates varied in the first seconds of the injection period and initial flow rates were approximately 20% above the final constant injection rate. This was due to the long length of the injection line and initial pressure buildup in the line in between the pulses. The measurements shown were performed after 8 hours of constant injection to allow background concentrations in the room to stabilize. Infiltration in the room was measured to be constant at 0.37 air changes per hour using a tracer gas decay test.

DISCUSSION OF RESULTS

Table 1 shows a summary of the results obtained. The ratio of the maximum concentration of pulse P1 over pulse P2 is 2.6 and is close to the ratio of 3 for the average injection rate of P1 over P2. Since the number of measurement is high, the area under the curve of the pulses can be estimated by summing all the concentrations in time. If we correct the concentrations of P2 and add to them the difference between the minimum concentration of P1 and the minimum concentration of P2, we obtain a corrected pulse, P2*, as shown in Figure 4. The corrected pulse allows us to compare the area under the two pulses irrespective of the background concentration in between pulses and a ratio of 1.5 is obtained if divide the area under P1 by the area under P2.

CONCLUSION

At this stage, preliminary results indicate that the method discussed here is able to measure and approximate reasonably well the dilution process occurring in the test room. The next step will be to sharpen the profile of the injection pulses and, to repeat the same measurements with higher ventilation rates to obtain data for dilution as a function of ventilation. The method will also have to be tested for various space layouts and to account for the presence of other carbon dioxide sources in the room. After these results will be available, it will be possible to simplify the method further by determining the optimum sampling rate required to describe the pulses accurately.

ACKNOWLEDGEMENTS

This work is supported in part by the contribution of the Institut de Recherche en Santé. et Sécurité du Québec (IRSST). We would like to thank Bob Robb, chief technician for McGill's Occupational Health Department for his contribution to the test chamber.

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TABLES AND FIGURES

Table 1: Comparison of pulse P1 and P2

Parameter	units	P1	P2	Difference P1-P2	Ratio P1/P2
Average injection rate	Lpm	0.3	0.1	0.2	3
Maximum	ppm	4561	1788	2774	2.6
Minimum	ppm	622	433	189	1.4
Average	ppm	1197	633	564	1.9
Sum of concentrations	ppm	1.08E+06	5.72E+05 •	5.09E+05	1.9
Adjusted sum	ppm	1.08E+06	7.42E+05 •	3.38E+05	1.5
Number of observations		903	903		

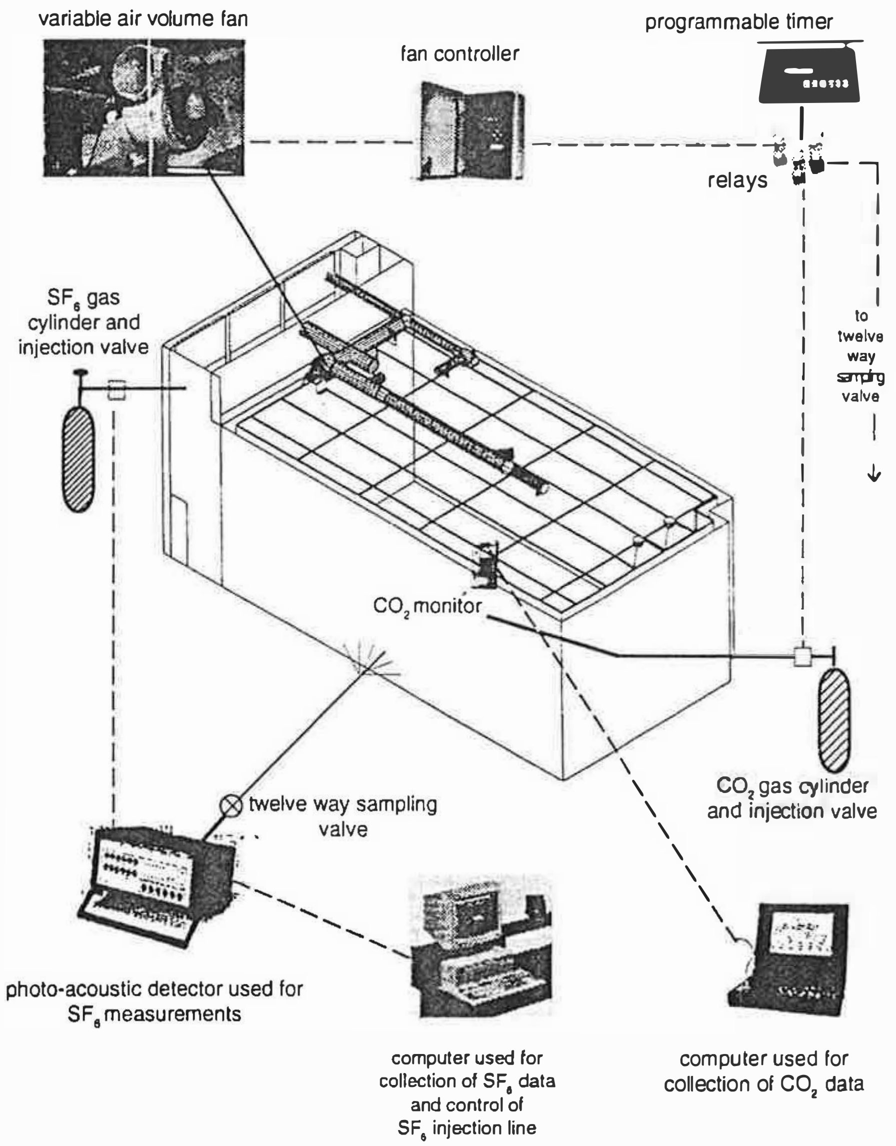
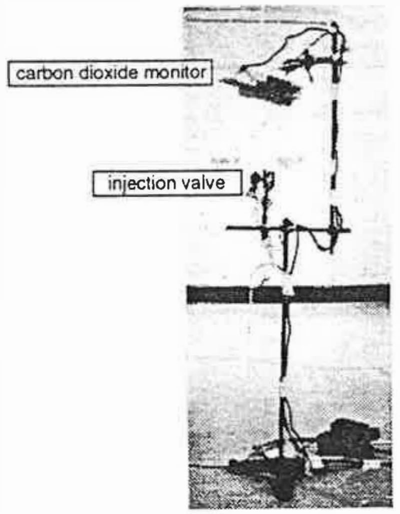
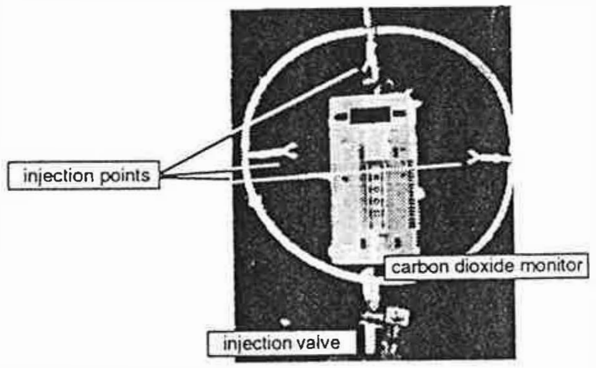


Figure 1: Data acquisition and injection systems



a) injection tripod



b) injection system with circular diffuser (front view)

Figure 2: Injection system for carbon dioxide

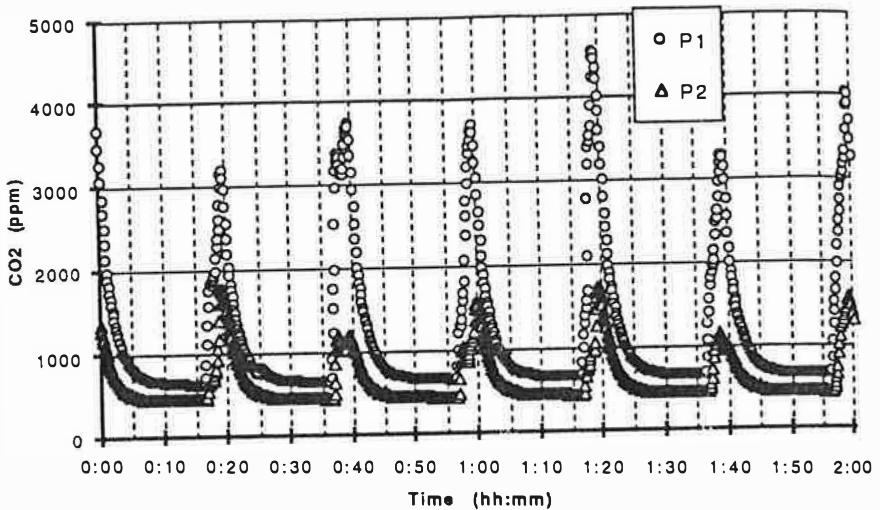


Figure 3: Concentrations of CO_2 measured over two hours for pulses P1 and P2

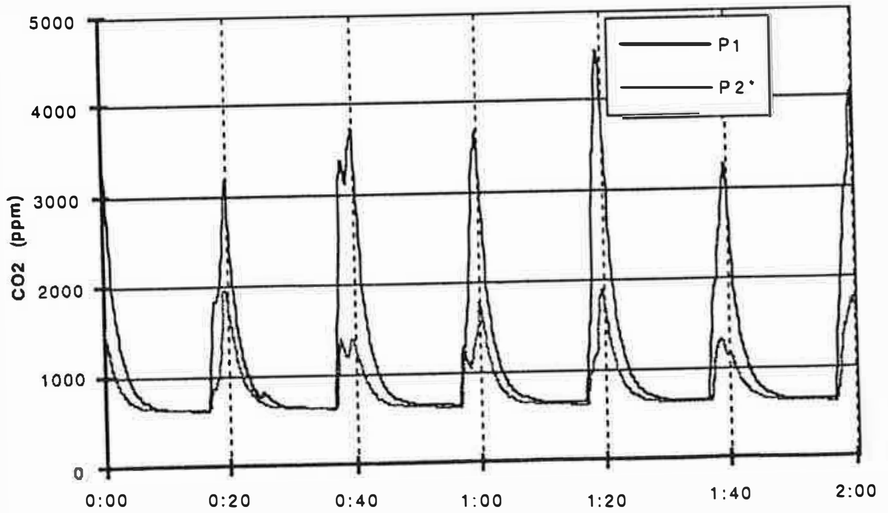


Figure 4: Pulse P2 modified for background concentrations

ESTIMATION OF INDOOR AIR POLLUTION BECAUSE OF THE OUTDOOR ENVIRONMENTAL POLLUTION

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ABSTRACT

Taking into account the physical aspects connected with the approached subject,particularizing the fundamental equations of gasodynamics,it is possible to obtain the diagnostic and prognostic equations by constructing a mathematical model,able to describe analytically the contribution of outdoor air pollution (of different natures) to the indoor air pollution.

Restricting the field to the evolution of some toxic gases concentrations (CO, SO_2, NO^x),the applied part of the paper tries to establish some relations for estimating the pollutants transfer from the outside to the inside of a building, using the irreversible thermodynamics methods and the results of "in situ" determinations.

INTRODUCTION

The ensemble outdoor environment-indoor air is constituted like a synergetic system,wherein mass,energy and impulse transfer phenomena are to be met.In the absence of considerable internal sources,indoor air pollution is dependent on the degree of external environment pollution.

In order to verify how different air pollutants concentrations inside the building are integrated within the admissible limits,mathematic models are required,which are able to describe the evolution of pollutants concentrations based on information received from the stations controlling the important sources of atmospheric pollution.

THE DIAGNOSTIC AND PROGNOSTIC EQUATIONS

Taking into account the restricted field of the atmosphere near the earth,the gasodynamics fundamental equations,written in Euler's variant have the expression of balance equations.

The motion equation (impulse balance) can be written in the following way:

$$\frac{\partial \bar{w}}{\partial \tau} = -\bar{w}\,\bar{\nabla}\,\bar{w} - \frac{1}{\rho}\nabla p - g\frac{\bar{r}}{r} + \frac{\bar{\mu}}{\rho}\nabla^2\bar{w} + \frac{1}{3\rho}(\mu+\mu')\,\nabla(\nabla\bar{w}) \qquad (1)$$