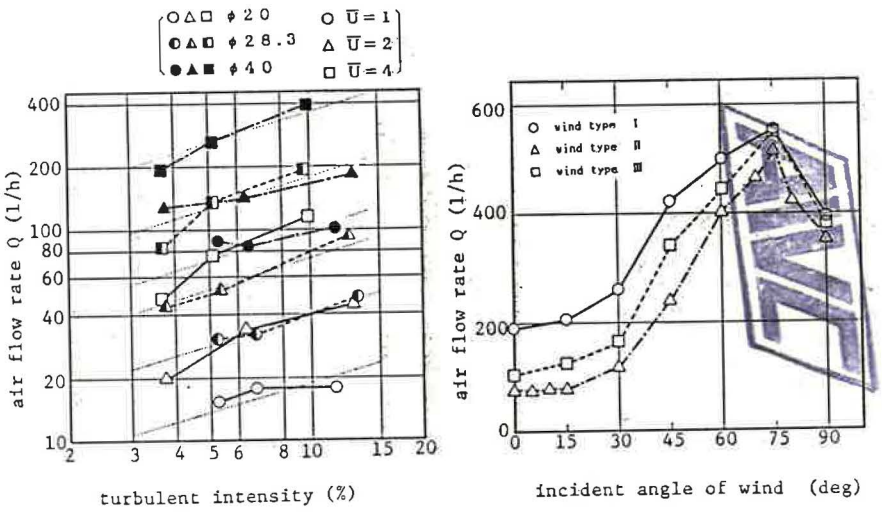

Fig.6 The measured air flow rate as a function of turbulent intensity on full logarithmic axes. (the incident angle =0)

Fig.7 The measured air flow rate as a function of incident angle of wind.

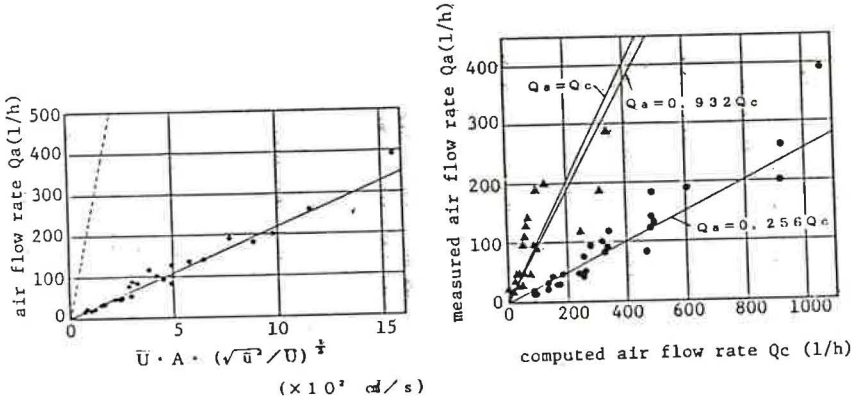

Fig.8 The measured air flow rate as a function of the product of mean air velocity, opening area and the half power of turbulent intensity. The simple equation by Cockroft et al. is drawn in a broken line.

Fig.9 The comparison between the measured air flow rate and computed flow rate. ●:from the non-filtered data of air velocity ▲:from the high-cut filtered (over 100Hz)data of air velocity.

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EVALUATION OF LOW-COST TRACER TECHNIQUES FOR MEASURING AIR EXCHANGE RATES IN BUILDINGS

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Abstract

The aim of this study was to find and evaluate a simple detector or method for routine air exchange rate measurements in dwellings and office buildings. The experimental work was mainly focused on evaluating a semiconductor sensor for the detection of freon 12 (dichlorodifluoromethane). The applicability of carbon dioxide indicator tubes for air exchange measurements, CO_2 as a tracer gas, was also studied. It was found that these methods can be used only when an approximation is sufficient.

Introduction

A common method for measuring air exchange rate or air infiltration characteristics in dwellings and office buildings uses the dilution of a tracer gas. In this method a small quantity of a tracer gas is introduced into the room, mixed homogeneously, and the concentration of the tracer gas versus time is recorded. The concentration of the tracer gas is usually measured with sophisticated instrumentation. Two approaches for tracer gas monitoring are in general use. The sampling tubing is installed in the building and the concentration is analyzed continuously or at certain time intervals with an IR analyzer, electron capture detector gas chromatograph or a portable masspectrograph (2, 3, 4, 6). Another technique is based on spot sampling and later analysis in the laboratory (1, 5). In both cases skilled analyzers and operators are needed.

Because the tracer gas technique is widely used in air exchange measurements, there is a current need to develop simple and inexpensive detectors for tracer gas monitoring. The aim of this study was to find and evaluate a simple detector or method for routine air exchange rate measurements in dwellings and office buildings. The experimental work mainly focused on evaluating a semiconductor sensor (TGS, Figaro Engineering Inc.) for the detection of freon 12 (dichlorodifluoromethane). The applicability of carbon dioxide indicator tubes for air exchange measurements, CO_2 as a tracer gas, was also studied.

Methods

The gas sensitive semiconductor TGS sensor is based on the n-type sintered SnO_2. The detector contains a heating coil and a gas detecting element. When combustible or toxic gases

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are adsorbed on the surface layer of the sensor, a marked change in electrical resistance occurs. The adsorption of gases on the sensor surface is reversible, i.e. desorption can also occur. The sensor resistance decreases exponentially with the increasing gas concentration. The detector reacts to all combustible gases, but the sensitivity for specific gases may be increased to some extent by adjusting the sensor temperature and doping impurity atoms in the sensing material. The function of the detector is also affected by the air humidity.

Initially, eight different TGS detectors were evaluated at various stationary freon 12 concentrations ranging from 2 to 100 ppm. Model 815D had the greatest response to freon 12. Therefore, it was selected for further testing. As the detector has notable zero drift, dynamic calibration was performed. The calibration was carried out with the exponentially decreasing gas profile (from 160 ppm to 30 ppm) corresponding to an exchange rate of 1.5 h^{-1}. The concentration in the calibration chamber was measured with a Miran 1A infrared analyzer (Foxboro Analytical).

The air exchange rate measurements with the calibrated sensor were done in a test room (volume: 32 m^3) where airflow rate can be accurately adjusted. Three different air exchange rates (0.5, 1.0 and 2.0 h^{-1}) were used. The test room was filled with freon 12, mixed homogeneously with a table fan, and the decrease in concentration was monitored. In test 2, with air exchange rate of 0.5 h^{-1}, no table fan was used. The initial concentration at each test was about 150 ppm.

The air exchange rates in an office room (volume: 28 m^3) were determined by using carbon dioxide as the tracer gas. The concentration decay was measured with CO_2 indicator tubes and the Miran 1A infrared analyzer. The initial concentration varied between 1500 and 3000 ppm. At least seven samples were taken.

Results

Air exchange rates measured with the TGS semiconductor sensor are presented in Table 1. Typical concentration decay curves of freon 12 are shown in Figure 1. The results of CO_2 measurements are presented in Table 2.

Table 1. Air exchange rates measured with the TGS-815D semiconductor sensor and the Miran 1A infrared analyzer (Freon 12 as the tracer gas)

Test no.	Air exchange rate (h^{-1})	
	Miran 1A	TGS-815D
1	0.53	0.61
2	0.52	0.48
3	1.04	0.74
4	1.97	1.71
5	2.98	3.32

Table 2. Air exchange rates measured with carbon dioxide detector tubes and the Miran 1A infrared analyzer (CO_2 as the tracer gas)

Test no.	Air exchange rate (h^{-1})		
	Miran 1A	CO_2 detector tube	Number of tubes
6	0.58	0.50	11
7	2.18	1.52	9
8	2.50	2.76	12
9	2.9o	2.00	7

Discussion

Air exchange rates measured by the TGS-815D detector differed on average 15 % from the reference values obtained by the Miran. The lowest difference (8 %) was obtained at air exchange rate of 0.5 h^{-1} and the highest one (29 %) at 1.0 h^{-1}. The highest difference was due to disturbing compounds in the test room air, causing a clear deviation from the exponential decay. Irregular deviations in exponential decrease occurred also in the other tests. It was observed that organic solvent and changes in the humidity of the air caused disturbances to the TGS detector.

Air velocity above 2 m/s affected the function of the TGS sensor. Therefore, the detector is not suitable for concentration measurements in ducts or supply air and exhaust air openings.

To sum up, the TGS-815D semiconductor sensor is applicable to freon 12 monitoring in rather clean environments. Under favourable conditions, air exchange rates may be determined at an accuracy of 15 %. The function of the TGS detector might be more reliable at higher concentrations, i.e. at several hundred ppm.

When the CO_2 indicator tubes were used, the results deviated 10 - 30 % from the reference values. In addition to the limited accuracy of the indicator tubes, the high background concentration of CO_2 presents a problem. The variation in the background concentration because of spurious sources such as metabolic CO_2 release of the occupants may result in more erroneous values than those of the present tests. Therefore, the CO_2 indicator tubes can be used to measure air exchange rates only when an approximation is sufficient.

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Figure captions
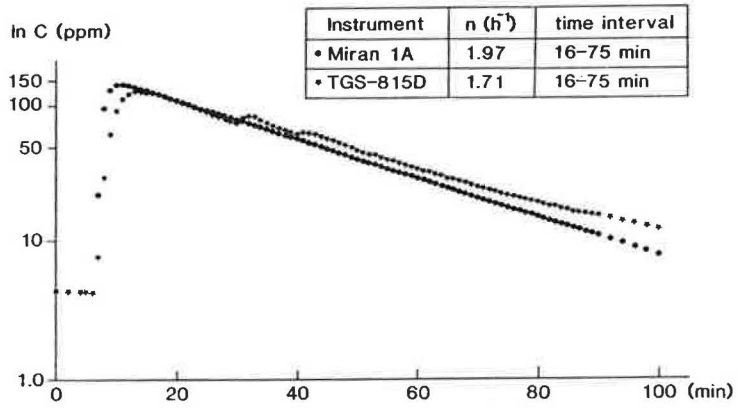
Fig. 1 Typical concentration curves of freon 12 measured with the TGS-815D semiconductor detector and the Miran 1A infrared analyzer (n=air exchange rate).