A COMPUTER-CONTROLLED SYSTEM FOR MEASURING BUILDING AIR EXCHANGE RATES USING SULFUR HEXAFLUORIDE AS A TRACER GAS

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Abstract

A computer-controlled system for measuring air exchange rates in large buildings has been developed. The system consists of a data acquisition unit controlled by a personal computer, a gas chromatograph equipped with a molecular sieve column and a scandium-tritium electron capture detector, a weather station, and a carbon dioxide analyzer. The system is capable of monitoring up to sixteen different locations, automatically calibrating itself, and displaying ventilation rates at the end of the sampling period. One of the important features of this system is that oxygen is prevented from entering the electron capture detector, thus reducing the time between samples and extending the life of the detector.

Introduction

It has been reported (3,4) that a strong relation exists between ventilation and indoor air quality. Unfortunately, little work has been done to elucidate the interaction between mechanical ventilation, infiltration, and indoor air quality. One of the reasons that such data is not available is the complexity involved in measuring ventilation rates of large buildings (2,5).

Tracer gas dilution is a technique that has been widely used for measurements of air infiltration and ventilation. This technique involves releasing a gas into the space under investigation and collecting air samples as the gas concentration decays (ASTM Standard E741 (1)). Usually several grab samples are collected simultaneously and analyzed in the laboratory at a later time. The system presented in this paper can be used to continuously monitor tracer gas decays at up to sixteen different locations in a building. This allows on-site determination of the air exchange rate at each location.

Concentrations of sulfur hexafluoride (SF6), the most commonly used tracer gas, are usually measured with the aid of a gas chromatograph, which separates the SF6 from the other gases, and an electron capture detector, which is capable of detecting very low levels of SF6. Resulting chromatograph peaks must be individually integrated and converted into concentration numbers with the use of calibration data. Frequent calibration of the ECD is required since the areas under the chromatograph peaks depend on the temperatures and flow rates of the gas chromatograph and electron capture detector. The system described in this paper can be preset to calibrate itself as frequently as the operator wishes.

Description of the system

The gas chromatograph and the Electron Capture Detector (ECD)

The gas chromatograph utilizes a 244 cm by 0.32 cm (8 ft by 1/8 in) stainless steel column packed with washed molecular sieve 5A, 80/100, and an electrically actuated gas sampling valve with a one cubic centimeter sampling loop. This particular column allows the SF_6 peak to elute first, thus permitting detection of low level signals which might otherwise be lost in the tailing portion of a strong oxygen peak.

After SF_6 has been separated from other volatile compounds, an electron capture detector with a tritium-scandium source is used for quantitation. One of the unique features of this system, the block diagram of which is shown on Figure 1, is that it prevents the oxygen peak from contaminating the detector. This is accomplished with an electrically actuated four-port valve which has been added between the column and the detector. This valve allows the oxygen, which follows the SF_6, to be vented, thereby preventing entry into the electron capture detector. This is needed since entry of oxygen would poison the detector, necessitating frequent heating at 320 $^{\circ}$C for a period ranging from a few minutes to several hours, or possibly even detector replacement.

The column is initially conditioned overnight at 250 $^{\circ}$C while the detector temperature is set at 320 $^{\circ}$C. During the conditioning period the column effluent is vented and clean carrier gas flows through the detector. At the end of the conditioning period the column temperature is set at 75 $^{\circ}$C, the injector temperature is set at 100 $^{\circ}$C, and the electron capture detector temperature is set at 130 $^{\circ}$C . A constant carrier gas flow of about 60 cc/min is maintained through the column and the detector.

The carrier gas used is nitrogen which has been purified by means of an oxygen scrubber and a moisture trap. Stainless steel tubing is used so that sorption of oxygen or other electron capture gases on the inside surface can be minimized.

The sampling system

A 16-position valve is the key component of the sampling system. This valve is capable of sampling up to 16 different locations with the aid of flexible tubing. The design of this valve is such that all the air streams but the one being analyzed continuously flow from the different remote sampling points to a common pump. The stream being analyzed is isolated, and a second pump is used to draw air from the remote location through the sampling loop and the three way valve (see Figure 1). When the sampling valve is activated, the air collected in the sampling loop is mixed with carrier gas and flows through the column and the electron capture detector.

Tygon tubing was tested for sorption of SF_6 of various concentrations lower than 1 ppm and was found to be satisfactory.

The calibration system

In the field, three cylinders of different SF_6 concentrations are used to establish the calibration curve appropriate to the temperatures and flows of the column and the detector pertinent to a particular experiment. These concentrations are: 10.6 ppb, 52.6 ppb, and 494 ppb. The three different calibration streams are selected with the aid of a ten-position valve. Position #1 of the 10-position valve is connected to the 16-position valve, whereas positions #2, #3, #4 are connected to the calibration gases. The outlet of this 10-position valve is in turn connected to the sampling loop and the three way valve (see Figure 1). The purpose of this three-way valve is to vent the flow past the sampling loop when calibration is in progress (during which time high pressure cylinders are used).

The correlation coefficient obtained by the least-square linear fit to the above mentioned concentrations is approximately the same as that obtained using these points and three additional concentrations, namely 9.424 ppb, 96.51 ppb, and 940 ppb. For simplicity in the field, therefore, the first three points are deemed sufficient for calibration.

Other instrumentation

A CO_2 monitor is connected downstream from the sampling loop so that the CO_2 levels can be measured concurrently (under some conditions, ventilation rates can be estimated from these levels). A weather station is also in use for monitoring the outdoor wind speed and wind direction, since both of these parameters affect a building's ventilation rate. In addition, several portable, self-contained, battery-operated recorders capable of monitoring and recording the indoor and outdoor temperature and humidity levels for up to seven days are also used.

Computer-controlled data acquisition and instrument control

An interface unit controlled by a personal computer is used for data acquisition and instrument control. Specifically, this unit reads the frequency and analog outputs of the electron capture detector, the analog outputs of the CO_2 monitor and the weather station, the digital output of the two multi-position valves, and selects the positions of all five valves.

Parameters selectable by software include the start and end positions of the 16 and 10 position valves, the time between calibrations, the time between air samples, and the duration of the total sampling period. After each injection has been completed, calculations of SF_6 peak areas are performed and saved on a disk file. At the end of the sampling period, the calibration data is used to convert the SF_6 peak areas into concentrations. Then the concentration for each zone is plotted against time, and the ventilation rate is calculated for the time period specified by the operator according to ASTM Standard E741 (1). This is repeated for all sampled zones, and in the end the average ventilation rate is displayed. A similar procedure is employed with the CO2 data. Finally, the wind speed and wind direction are plotted against time, and the average values of these variables for the duration of the study are also calculated.

Conclusions

A computer-controlled system for measuring air exchange rate(s) of buildings has been developed. All the instrumentation comprising this system is mounted on a cart, thus minimizing the set-up time, and enabling the operator to easily transport the system. Indoor air quality researchers are thus able to obtain the ventilation rate(s) in the indoor environment under investigation on-site, enabling them to decide whether further ventilation data is needed, and/or whether the study should be repeated under different ventilation conditions.

The data collected using this air exchange rate measurement system will be used to investigate the interaction between mechanical ventilation, infiltration, and indoor air quality.

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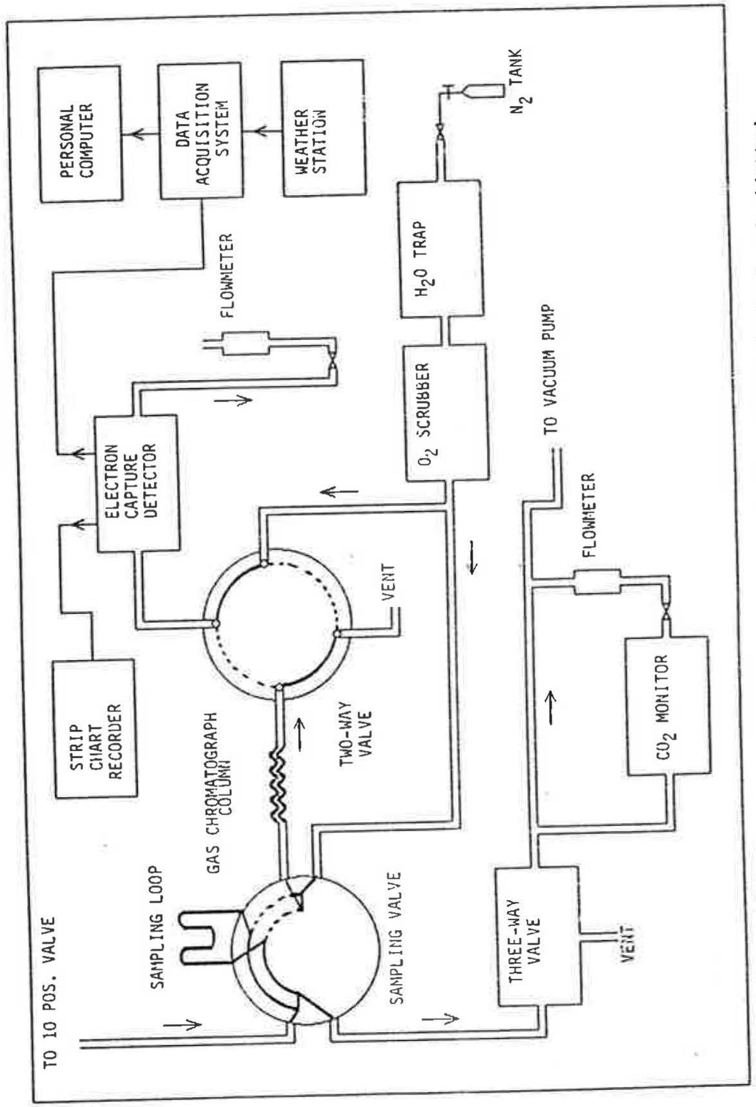

Fig. 1. Block diagram of SF6 computer-controlled system in load mode (dotted lines indicate inject mode)