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A MODIFIED TRACER GAS INFILTRATION METHOD FOR USE IN A RESIDENTIAL INDOOR AIR QUALITY/WEATHERIZATION STUDY

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Abstract

As part of a study to evaluate the effects of home weatherization on indoor air quality, a tracer gas method to determine infiltration rates was developed by modifying existing methods to meet several project constraints. A method was needed that did not involve occupant participation, required only a small amount of time from the field investigators and had to be fabricated from rugged, low cost materials that could be easily transported. The method developed is based on the continuous release of pure sulfur hexafluoride (SF_6) from a cylinder and the transfer of indoor air to a storage bag. The collection bags were analyzed for SF_6 concentration by gas chromatography using an electron capture detector. The concentration of SF_6 along with tracer release rates and house volume measurements were used to calculate an air exchange rate for each home studied. Fifty homes were evaluated several times each using this method under varying weather conditions before and after energy conservation improvements were performed.

Introduction

In the fall of 1982 a comprehensive 2-year study was initiated to determine the effects of upgrading home weatherization on the indoor air quality of fifty Wisconsin residences. The scope of the study provided that each of the fifty homes was to be tested three times prior to and after a weatherization program for various pollutant concentrations and determination of the air infiltration rate. The tests were conducted in the late fall, mid-winter and early spring when Wisconsin homes are closed up for the heating season. The homes for this study were obtained from a group of natural gas users who were elderly, fixed income or handicapped which meant that testing methods had to be chosen that did not require assistance of the home residents. Due to the wide variety of parameters monitored and the number of homes in this study, a limited amount of time was available to qualified field personnel for performing field tests.

Although this study involved the measurement of many parameters (7), this paper discusses only the air infiltration measurements involved.

Method Development

Several existing methods were examined for determination of air infiltration rate including methods that measured tracer gas dilution (3,4,5,6,8) and constant tracer release methods, both passive and automated (1,2). Each of the methods studied had drawbacks which caused them to be poor candidates for use in this project. The tracer dilution method is designed for short term measurements of several hours and this study was designed to test the other parameters for 24 hour periods. Tracer dilution also requires that accurate determinations of sample collection times be made (5) and recorded on site meaning a field investigator remaining in each home over 3 hours or having homeowners collecting samples and recording times. This method is also susceptible to mixing problems. If the first collection is taken too soon, thorough mixing may not have occurred and a data point is lost in the determination of the infiltration rate.

The other methods investigated involved the continuous injection of tracer gases into the home and sampling the air by the use of passive samplers or through the use of an automated sampler. Each of these systems appear to be superior to tracer dilution methods for arriving at an accurate determination of infiltration rate, however, in each case the cost of implementing the techniques was far beyond the scope of this study. Also, the analytical lab used for this study was already able to test for SF_6, making it the preferable tracer choice. The time required to set up for another tracer system would have caused an impossible strain on the project schedule.

In lieu of using one of the existing methods, a new method was developed to overcome the problems and to fit into the constraints of this study. The method developed was named the <u>Sulfer Hexafluoride Steady State Method</u>, and utilized SF_6 as a tracer material. It involved the continuous release of SF_6 into the home prior to and simultaniously with the collection of room air during the 24-hour air quality sampling period.

System Description

SF_6 Source Release Module

Tracer gas was continuously added to the home by a SF_6 Source Release Module (SRM) consisting of a small cylinder of undiluted SF_6 Equipped with a fine metering needle valve. The release rate was measured with a micro bubble meter which was made by attaching a side arm to a $0.1cm^3$ micropipet with $0.01cm^3$ divisions. A rubber finger filled with soap was then attached to the bottom of the pipet to allow introduction of a bubble into the pipet. Flow measurements were then made for a $0.01cm^3$ displacement. Corrections for temperature and pressure were not required for this measurement. A tracer gas flow rate in the range of 0.05 to $0.1cm^3min.^{-1}$ was found to be adequate based on the sensitivity of the tracer gas analyzer and the average house volume encountered.

When purchased, the cylinders had a pressure of 1725 KPa and contained 14 l of SF_6. The initial flow was set in the lab and monitored for several weeks to insure flow stability. Observations showed a continual, minute decrease of flow over the test period which led the investigators to assume a linear pressure and flow decay during the 24-hour testing periods. Calculations showed that the cylinders could operate for over 6 months, however, to maintain optimum flow rates, the units were returned to the lab periodically to reset the flow. After several resets, the cylinders showed a slight increase in decay rate, so, the decision was made to refill the cylinders to maximum pressure when the flow dropped to $0.02cm^3min.^{-1}$.

Due to the low source flows, any leakage in the source release module would have caused considerable error in the calculation of infiltration rate. For this reason, all connective fittings were Swagelok stainless steel, the outlet tubing was plugged and each system was placed under water to check for leaks. The cylinders were then secured to sheet metal frames, padded with foam rubber to minimize vibrations, and sealed in boxes for field use with the cylinder exhaust tubing routed through the box wall.

Tracer Collection Module

The Tracer Collection Module (TCM) houses an inexpensive air pump plumbed to the common part of a three part solenoid valve. An electronic timing circuit activated a relay which, in turn, energized the solenoid. Two variable potentiometers controlled the off time and the duration of the on time of the solenoid. In the unenergized state, room air is pumped through the solenoid's normally open port and returned to the room. In the energized state, the air is pumped to a 5 layer aluminized polyester collection bag. In this study, 10 l bags were attached to the solenoid's normally closed port and collected 6 to 8 l in a 24-hour period. The pumps that were purchased for this project deliver a flow of 7 to $10cm^3s^{-1}$ and the timers were adjusted to provide a pulse of room air to the collection bag every 20 s. This combination called for the solenoid to be energized approximately 0.2 s. This time, adjusted using an oscilloscope, was tested several times for each unit to insure proper operation. A filter was placed between the pump and the solenoid to prevent particulates from causing cross leaks in the solenoid. The unit was contained in a flat cardboard box with padding and styrofoam to muffle the noise.

Infiltration Measurements

Deployment and Retrieval of the System

Since a number of air quality parameters were measured in this study requiring several short visits to each home, the SRM could be placed in the home 24 hours prior to each testing period. This early placement allowed the gas cylinders to reach indoor temperature, establish a stable flow and allowed the home to reach a uniform steady state concentration.(1,5) The SRM was placed in a location where it would not interfere with the occupant's daily activities, yet in a central location. In homes with forced air central heating the SRM was placed close to a cold air return to allow the furnace fan to assist in the mixing of the tracer gas and help the home reach an equilibrium concentration. An overriding concern in placing the SRM was to insure that it was not subjected to direct sunlight during the day or located in an area with severe temperature fluctuations caused by the home's heating system. After the initial 24 hour equilibration period, when the air quality measurements were to begin, the TCM was placed in the home with a clean, evacuated collection bag. At this time, several flow measurements were made on the SRM using the microbubble meter previously described. The TCM was required to be placed in a central area representative of average living space conditions, away from any areas that would experience extreme air infiltrations or exfiltration such as external doors or fireplaces. In addition, an effort was made to place the TCM in a location where the occupants spent most of their time.

Collection of the system after the air quality monitoring period required unplugging the TCM from the electrical outlet and obtaining several final flow measurements on the SRM. Since the bag is effectively closed when the solenoid is not energized, the collection bag can be left in the TCM for transportation to the lab for analysis. Precise sampling beginning and ending times are not required for this system nor are precise volumes of sample necessary, since an integrated sample of home air is collected over a 24-hour period.

Laboratory Analysis

The SF_6 concentration in the TCM collection bags was measured by Ni^{63} Electron Capture-Gas Chromatography (ECD-GC). Separation of the SF_6 from Oxygen, another electron capturing gas, was achieved using a molecular sieve column. The GC output was connected to a Varian model 401 data system which computed actual SF_6 concentrations by integrating sample peaks and comparing these peak areas to those from standard concentrations of SF_6. A typical chromatograph-data system calibration point that coincided with SF_6 concentrations found in the bags was 50ppb. Linearity of the GC was verified by injecting standards ranging from 10 to 100 ppb. The calibration standards were prepared in 1.5 l aluminized polyester bags by adding SF_6 to ultra high pure Nitrogen.

Calculations

As described previously (2,5), the equation for determining the rate at which ventilation air enters a dwelling v can be simplified to

$$v = \frac{f}{c} \tag{1}$$

where c is the concentration of tracer obtained from the TCM bag and f is the rate of tracer generation which was obtained from the SRM measurements. From this, the air infiltration rate I, in air changes per unit time can be calculated from

$$I = \frac{v}{V} \tag{2}$$

where V is the volume of the tested structure. The previous equations incorporate several assumptions. They assume that the outside air v entering the structure is free of SF_6 and that the released tracer reaches a homogeneous concentration throughout the house. The method also assumes that the entire structure acts as a single compartment with all areas having equal infiltration.

Conclusion

A limited number of replicate TCM's were used for multiple collections and the results of these tests show that the method seems to be relatively insensitive to mixing problems. The method was also tested against several existing methods including a passive steady state method (2) and the resulting correlation was encouraging. Future work will provide additional comparisons with other tracer methods and the increased use of multiple TCM's.

Based on the initial field data collected to date, the SF_6 Steady State Method has proven to be a convenient procedure for the determination of air infiltration rates in homes where the occupants cannot participate or where project constraints prevent the presence of trained personnel for extended periods of time.

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