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THE CONTINUOUS ANALYSIS OF AIR INFILTRATION IN A RESIDENTIAL ENVIRONMENT

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Abstract

An automated 10-point air sampling network which uses an electron capture detector gas chromatograph to continuously measure changes in sulfur hexafluoride tracer concentration in a residential environment will be described. The injection of the tracer is controlled by a microprocessor which decides to inject sulfur hexafluoride tracer to return its concentration to a preprogrammed set point. Infiltration rates from fan induced pressurization will be compared to the infiltration rates as reported from the replacement of sulfur hexafluoride tracer. The tracer will be injected at one of three locations. The resulting tracer concentration, which is computed as either a simple average or a volume weighted average by location, will be compared to the fan induced infiltration rate.

Introduction

The DiNardi/Rush-Hampton house is a 3600 square foot contemporary passive solar house located in Amherst, Massachusetts, USA. Instruments continuously analyze for selected indoor air pollutants, infiltration, ambient meteorological conditions, insulation, energy consumption and indoor thermal comfort parameters. The air sampling and analysis network includes a 10-port air sampling system interfaced to a gas chromatograph, a 5-port all teflon sequential air sampling system interfaced to a continuous formaldehyde analyzer and a 256 channel data acquisition system which is described elsewhere in these proceedings (3). As a part of this project, to characterize and control indoor air pollutants, an automated air infiltration measurement system using a sulfur hexafluoride tracer technique was designed and installed in this live-in laboratory. Although this technique is not unique (4) and its accuracy has been reported (5), its use with and without the forced circulation of the tracer and using various weighting techniques is not reported in the literature.

Tracer Injector System

The tracer injector system consists of standard gas chromatography hardware items. The valve that controls the amount of tracer injected is fabricated from a 6 port gas sampling valve with a 200 μl sampling loop and a motorized valve actuator and located in a valve oven (Carle Instruments Inc., Anaheim, CA, USA, Valve Model 2918, Automatic Actuator Model 4200 and Valve Oven Model 4301). This oven maintains the injector valve at $50^{\circ}C \pm 2^{\circ}C$. The sampling loop purge gas flow is operated by a solenoid actuated valve controlled by the data acquisition system. In the fill mode any tracer that is vented from the valve is removed from the building proximity and passed through a granular teflon scrubber. To assure that fugitive tracer is not entering the building envelope in a uncontrolled fashion an ambient location is sampled for sulfur hexafluoride contamination.

The Electron Capture Gas Chromatograph

The sampling and analysis for injected tracer is accomplished by a microprocessor-controlled gas chromatograph (Baseline Industries, Lyons, CO, USA, Model 1030A) equipped with a tritiated-scandium electron capture detector (Valco Instruments Co., Houston, TX, Model-140 Wide Range ECD System). This detector is a beta source with approximately 1 curie of activity, an area of 1.6 square centimeters, a baseline current of at least 2×10^{-8} amperes and a detector volume of only 180 microliters. The gas chromatograph is operated with a 6 foot long by 0.125 inch outside diameter type 301 stainless steel column packed with 60/80 mesh 5A washed molecular sieve (Alltech Associates, Deerfield, IL, USA). The column is maintained at $30^{\circ}C$ using scrubbed pre-purified dry nitrogen carrier gas. This carrier flow is 30 ml/min in the foreflush mode and 40 ml/min in the backflush mode. The electron capture detector is operated at $200^{\circ}C$. The retention time of the tracer is 0.3 minutes. Oxygen and other ECD sensitive materials are backflushed to vent which results in a recycle time of 4 minutes per location. This system is capable of detecting sulfur hexafluoride in the parts per trillion concentration range.

Multipoint Air Sampling

The multipoint air sampling network consists of a 10-point rotary gas sampling valve (Valco Instruments Co., Houston, TX, USA, Model AH-10). The mulitpoint air sampling system consists of cleaned eighth inch o.d. copper sampling lines which extend from the 10-port rotary gas sampling valve in the laboratory to sampling ports throughout the house, as well as an ambient point away from the building envelope. Refrigeration grade copper tubing was cleaned by a solvent rinse technique using methanol then acetone. The tubing was dried at 100°C for 48 hours under a dry nitrogen carrier flow. The locations sampled are the zero air supply, calibration gas supply, ambient air and seven locations throughout the house including the living room, master bedroom, kitchen, garage, laboratory, family room and recirculation air plenum.

Fan Pressurization Method (2)

The live-in laboratory is equipped with a permanently mounted device to measure air leakage by the fan pressurization method. This consists of a 48 inch axial flow belt-drive fan (Dayton Electric Manufacturing Co., Chicago, IL, USA, Model 3C156). The drive motor is a 1.5 horsepower variable speed direct current motor (Dayton Electric Manufacturing Co., Chicago. IL, USA). The motor and drive sheaves are toothed cast iron connected with a fiberglass reinforced timing belt (T.B. Woods Co., Chambersburg, PA, USA) to eliminate belt slippage. Drive motor RPM is continuously monitored with a time base tachometer (Red Lion Controls, York, PA, USA, Model Ditak IID). The device was calibrated using an orifice pressure drop technique (1).

Infiltration Analysis

A series of experiments will be performed where the tracer is injected at one of the three locations available. These locations are either on the lower level, on the second level or in the recirculation air plenum. These injections will be performed under conditions of air leakage induced by fan pressurization, with and then without the air recirculation system operating.

Two subsets of experiments will be performed each using a different averaging method to report the tracer concentration. This value is then used to control the injector to return the tracer to the predetermined set point concentration. One subset results in a simple mean of the tracer levels reported at the seven locations. The other subset results in a concentration that is a volume weighted average by location. The volume weighted average will be computed by assigning different sampling points to separate volumes in the structure. These corresponding volumes will be estimated and the volume weighted average computed. The infiltration rate is a measure of the amount of make-up tracer that has to be added to the structure to maintain the desired set-point concentration. These values will be compared to the fan pressurization infiltration rate.

References

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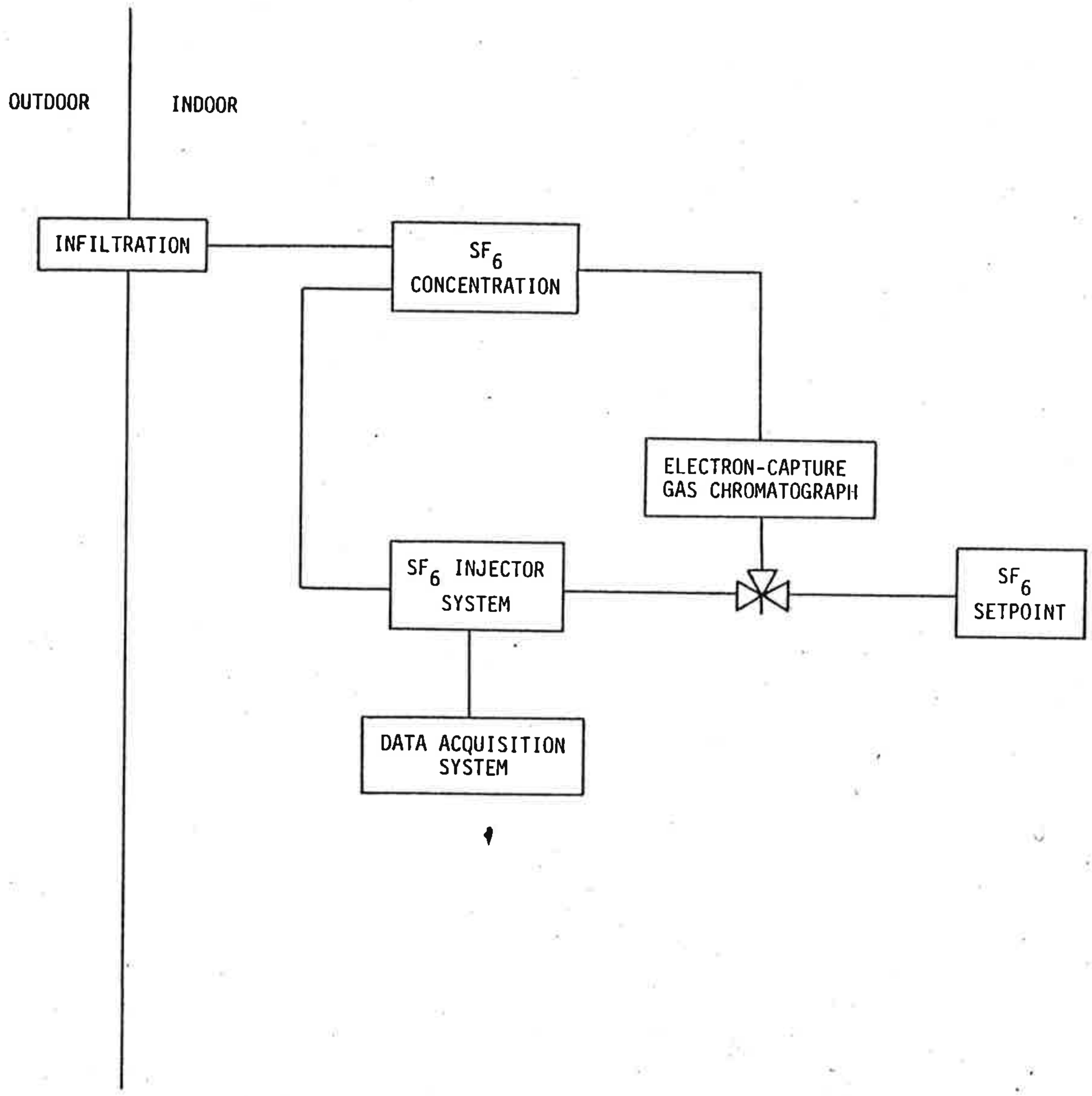

Figure 1
Infiltration Measurement System