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A Low-Cost Method for Measuring Air Infiltration Rates in a Large Sample of Dwellings

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A method for collecting air infiltration data in a large sample of dwellings is presented. The method consists of a tracer-gas dilution technique employing air sample bags which are analyzed in a central laboratory. The method will be applied to a Community Services Administration optimal weatherization demonstration in approximately 300 dwellings on 16 sites throughout the United States. The method will yield air exchange rates under typical heating season condition for each dwelling in the demonstrations. Preliminary data on air infiltration rates in low-income housing in Portland, Maine are presented.

Key Words: Air infiltration; air sample bags; energy conservation; retrofit; sulfur hexafluoride; tracer gas; weatherization.

1. INTRODUCTION

The leakage of air into and out of the living space of a dwelling is one of the major components of heat loss of a home. Though recent advances in instrumentation have made it possible to automatically measure the air leakage rate of a building, the techniques to obtain actual air leakage rates are both expensive and difficult. In an attempt to measure the actual air infiltration rates in low-income housing and to determine the effectiveness of various weatherization measures on reducing the air leakage in a home, a measurement technique using a tracer gas and air sample bags has been developed. Preliminary data on air leakage rates from homes in Portland, Maine have been collected. These measurements are part of an evaluation of a weatherization project undertaken by the Community Services Administration.

The Community Services Administration (CSA), in order to assess how it might help poor people to cope with increasing energy costs, has undertaken a weatherization demonstration project whose major goal is to provide data for determining the optimal level of weatherization which should be applied to the residences occupied by the poor in various climatic zones in the continental United States. The Center for Building Technology of the National Bureau of Standards (NBS) has been given the role of providing technical assistance and support for this demonstration. This role involves selecting demonstration cities, selecting homes in each city, selecting weatherization options both for the building envelope and the buildings' mechanical system, supervising the collection of the data from the demonstration, developing test procedures for evaluating the effect of weatherization on the homes, and analyzing the results of the demonstration. The demonstration project is to be undertaken in 16 cities. These are graphically shown in Figure 1, along with the degree days for each location. At each site, approximately 20 to 30 homes will be weatherized.

The principal measure of the effectiveness of the weatherization of each dwelling will be the observed reduction in the utility bills of the dwelling. However, in order to assess in more detail the savings from each option and to explain anticipated variations in the amount of saving accrued among the homes, a series of tests for both the building envelope and the mechanical system has been developed. The building envelope tests currently being planned consist of: 1) a thermographic survey of the exterior of the dwellings, 2) air infiltration tests, 3) determination of the interior temperature stratification, and 4) the determination of the existence of heat by-pass mechanisms into attic and basement. The infiltration tests will consist of: 1) a test method for determining the actual air leakage rates in each dwelling, 2) a fan pressurization test, and 3) a test for locating the air leakage paths still existing in the dwelling after weatherization, employing fan depressurization and an infrared scanner. The topic of this paper is to describe the test method for determining the air leakage rate in each dwelling.

In attempting to assess the air leakage charcteristics of a dwelling, in the author's opinion, four classes of questions are usually asked: 1) what are the actual air leakage rates occurring in the structure under various climatic conditions and usage patterns; 2) how tight is the building compared with other buildings and with itself after certain measures are applied to the building; 3) where are the leakage paths in the structure; and 4) what is the severity of each air leakage path. The actual air infiltration rate of a building is usually determined by the tracer-gas dilution method [1, 2]. The tightness of a building can be obtained by the tracer-gas method, but the fan pressurization method is easier to perform [3-5]. The location of air leakage paths can be observed using thermography, either under normal weather conditions [6] or in conjunction with pressurization of the building [5]. It is very difficult to determine the amount of air leakage attributable to each air leakage path. Attempts at this level of quantification usually consist of sealing the observed openings and using either the tracer-gas method or the pressurization method to determine the reduction in air leakage.

As mentioned above, the actual air infiltration rates in dwellings are usually determined by the tracer-gas technique. In the CSA weatherization demonstration, one would like to know the actual air leakage rates in each of the demonstration homes, at least after weatherization has been performed and preferably both before and after weatherization. Though the tracer-gas technique has the reputation of being difficult to perform and requires both highly trained personnel and expensive equipment, it is the author's opinion that this method can be modified through the use of air sample bags such that it can be applied to a large collection of dwellings by relatively inexperienced persons (possibly even the building occupant) in an inexpensive manner. The method will provide actual air exchange rates under various weather conditions which can be used to assess the typical air leakage performance of the building. The following sections will describe this method.

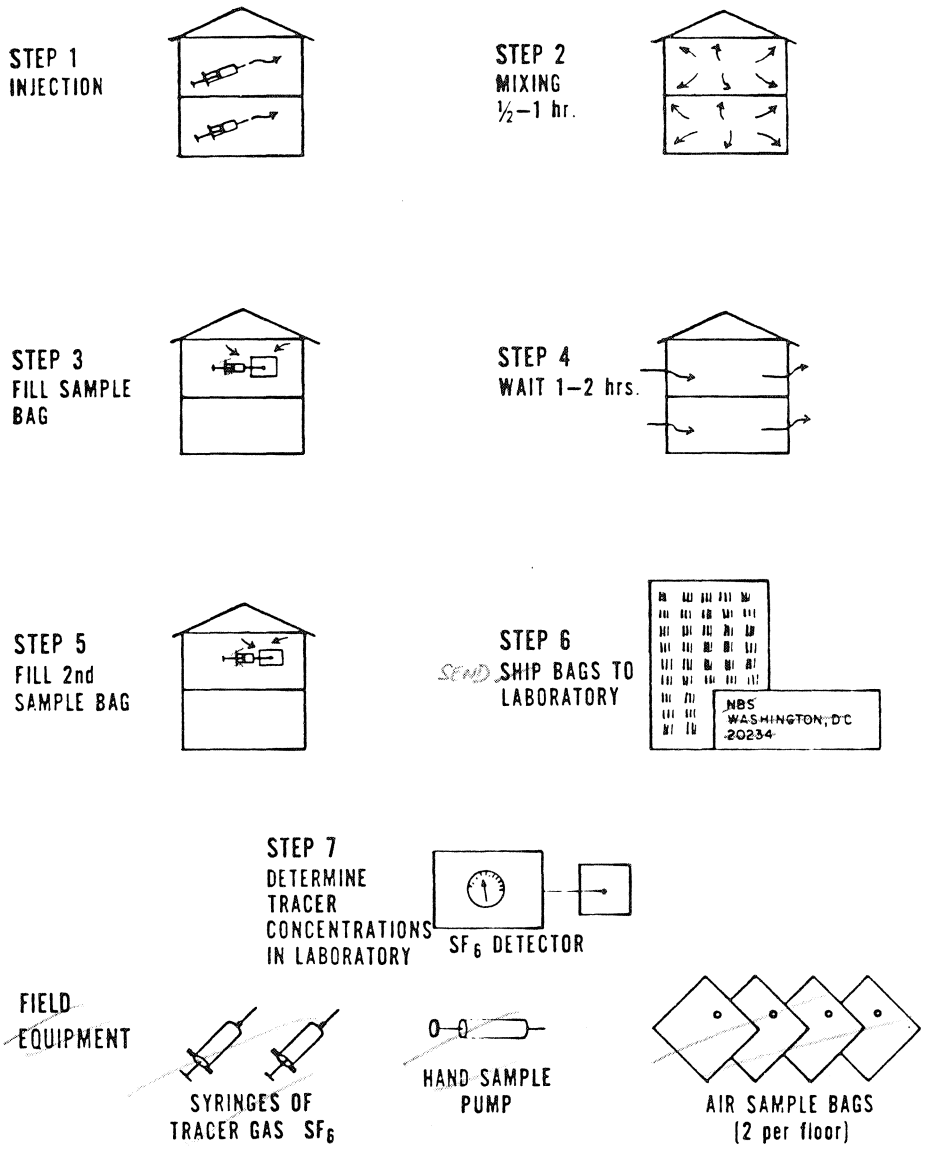

Figure 2. Outline of procedure.

where C_1 and C_2 are the initial and final tracer gas concentrations respectively, and $\Delta\tau$ is the time interval in hours between filling of the sample bags. For periods of 1 to 2 hours, equation (1) is an accurate manner for determining the air exchange (see Ref. [1]). The above steps are graphically shown in Figure 2.

The above-described method is easy to perform and inexpensive, and if several homes are grouped together can be accomplished at the rate of about 1 house per hour.

3. RESULTS OF PRELIMINARY TESTING

In order to assess the viability of the method for collecting air infiltration data, series of tests were run both in Portland, Maine in the dwellings that are being weatherized,and in a home in Maryland near the National Bureau of Standards. The first series of tests in Portland was done in order to obtain primary air exchange rates and in order to test the assumption of uniform mixing when the previously described injection procedure was applied. The concentration of SF_6 was measured at several points on each floor of the tested building. Usually no variations in tracer concentration occurred which would lead to appreciable errors in the air exchange rate for the floor. As mentioned previously, there was a tendency for the concentration of the tracer gas to be higher on the upper floors than on the lower floors. This observation was the main reason for specifying in the test procedure that separate air sample bags be used for each floor of the building. A summary of the air exchange rates for this test is given in Table 1. The house numbers marked with an asterisk* are buildings which have already been weatherized. These data showed that these buildings were experiencing relatively high air exchange rates.

In order to test the feasibility of using air sample bags, tests were run in a home in Maryland. The sample bags were first analyzed the day immediately following the collection of the sample. An air infiltration rate of 0.34 air exchange per hour was found. After a period of three weeks the sample bags were reanalyzed and an air infiltration rate of 0.31 was obtained. Any change in concentration in the gas sample was within the errors of the experiment, since no care was taken to calibrate the instrument at these times.

4. CONCLUSIONS

The preliminary testing of this method has indicated that it is a feasible method for obtaining air infiltration data at a low cost and using inexperienced personnel. Although the method does not produce a detailed trace of air exchange rate over a period of one to two hours, it does give the total air leakage of that period, and this is usually of primary interest to energy conservation analysis. The technique also produces integrated air samples for each floor and therefore minimizes the effects of non-uniform mixing.

The analysis of the air sample bags in the laboratory permits the use of standard laboratory techniques, such as dilution of the sample if the concentration of gas is above the saturation concentration of the detector, and the use of reference concentrations for each range of sensitivity of the detector--techniques which are difficult to apply in the field. The major disadvantage of this method is that it is a blind test and there are no checks in the field which can assure the accuracy to which the instructions are followed. It is planned to modify the automatic air infiltration equipment described in Reference [7] such that it can automatically handle 40 bags at a time. The possibility of automatically processing the air sample bags is the reason that air sample bags as large as 10 liters were chosen. The technique will be applied during the 1978-1979 heating seasons to the CSA weatherization demonstrations and further verification of its accuracy and reliability will be undertaken.

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[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A method for collecting air infiltration data in a large sample of dwellings is presented. The method consists of a tracer gas dilution technique employing air sample bags which are analyzed in a central laboratory. The method will be applied to a Community Services Administration optimal weatherization demonstration in approximately 300 dwellings on 16 sites throughout the United States. The method will yield air exchange rates under typical heating season condition for each dwelling in the demonstrations. Preliminary data on air infiltration rates in low-income housing in Portland, Maine are presented.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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