PARAMETERS AFFECTING AIR LEAKAGE IN EAST TENNESSEE HOMES

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Abstract

A major pathway for loss of conditioned air in east Tennessee homes with externally located heating, ventilation, and air-conditioning (HVAC) systems is leakage in the ductwork. The average infiltration rate, as measured by Freon-12 tracer gas dilution, nearly doubles if the central duct fan is operating; duct-fan on and duct-fan off measurements of the rate of air exchange gave mean values of 0.78 and 0.44 h^{-1}, respectively, in a total of 31 homes. Specific leakage areas measured by the blower-door, pressurization-depressurization technique are affected to a lesser extent by inclusion of the ductwork volume within the total volume of the house that is being pressurized; the average increment in the specific leakage area for a subset of 7 of the study homes is about 15%. For homes that have central HVAC systems, weatherization and energy conservation programs should be cognizant of the seriousness of air and energy losses that can be caused by leaking ductwork.

Introduction

More so than usual for a study of this nature, serendipity played a major role in guiding the course of the studies. What started as routine measurements of tracer gas air infiltration in support of an indoor air pollution study [1,2] became a study focused on the impact on air infiltration of the ductwork and the duct fan of HVAC systems. An apparently marked difference in the "natural" air exchange rate was first noted in houses with HVAC systems, dependent on whether or not the central duct fan had been running at the time of the tracer gas measurement. Double rather than single tracer gas measurements were subsequently made with and without the operation of the central duct fan in each house with a central HVAC. The study was later expanded to include blower-door measurements that either included or excluded the ductwork system in the pressurized volume of the house. The objectives were to evaluate quantitatively the impact of central ductwork systems and operating duct fans on air infiltration and air leakage parameters.

Procedure

Rates of air exchange were measured in 31 different houses by the tracer dilution technique. During a measurement, the exterior doors and windows of a house remained closed while the interior doors between the finished living areas were left open. The tracer gas, Freon-12, was sprayed throughout the house and dispersed with the aid of several portable floor fans that continually circulated air while the concentration decay was being measured. The concentration of Freon was monitored with an infrared spectrometer at 9.26 μm. A mathematical equation based on a well-mixed, single-compartment mass balance was used to model the data [3]. Two sets of tracer dilution data were obtained sequentially. In one instance the central duct fan of the central HVAC system was operated and in the other instance the fan was left off.

In a subset of seven houses, the induced pressure method was used to measure air tightness. The blower door [4] was temporarily installed in an exterior door of each house. Both fan-pressurization and fan-depressurization measurements were made. The specific leakage area (cm^2/m^2 floorspace) of a house, was determined graphically for a pressure differential of 4 pascals (0.016 inches of water).

Prior to measuring air leakage, the following openings in the house were covered with plastic and sealed with tape - open fireplaces, air exhausts above kitchen cooking ranges and exhausts for bathrooms.

Two types of blower-door measurement were made. In one instance, the air entry and exit vents to the duct system were left open. In the other instance the vents were closed by shutting the attached louvres and covering the entry and exit vents with plastic. Thus the volume of the duct system was either included or excluded from the total volume being pressurized or depressurized by the blower door. The central duct fan was left in the off position throughout the blower-door experiments.

Results

Some of the rates of air exchange obtained from measurements of tracer gas decay are reproduced in Table 1. The windspeed at the time of measurement was observed to be generally less than 10 mph.

For the 31 homes, the mean value of the rate of exchange between outdoor and indoor air in closed-up houses was 0.44 changes per hour (h^{-1}) when the central duct fan was switched off. With the central duct fan running, the mean air exchange rate was nearly doubled at 0.78 h^{-1}.

The results of the induced pressure measurements made in a subset of 7 houses are shown in Table 2. Each value specific leakage area (cm^2/m^2) is the mean of two leakage measurements in which the house was once being pressurized and once depressurized.

For house #1, pressure differentials were measured in the return duct at a location 3 m in front of the central duct fan. With the duct fan running, a decrement of 25 pascal (0.10 inches of water) was measured. At the same point in the ductwork, with the duct fan off but with the blower door depressurizing the main volume of the house to 25 pascal, the pressure inside the ductwork was also 25 pascal.

Discussion

The most striking finding was that for the 31 homes with central HVAC, the mean rate of "natural" air exchange was nearly doubled, from 0.44 to 0.78 h^{-1}, when the central duct fan was operating.

The dominant driving force for the enhanced air exchange is leakage of air from joints in the central ductwork at locations exterior to the principal living zones. These zones include garages, crawlspaces, attics, and in ductwork adjacent to heat pumps located outside the house. These leaks are readily detected by force of draft on the hand or with a smokestick. In return ducts under negative pressure, such as those often located in garages, the enhanced exchange will be due to ingress, rather than egress, of air (the pressure decrement was 0.10 inches of water for house #1). The results for houses #1 and 2 (Table 1) were typical of the norm. House #24, however, is of special interest. While thermally reinsulating the ductwork, the owner had also applied sealant to exposed joints in the ductwork. Presumably as a result of the leakproofing, the rate of air exchange was now desensitized to the on or off setting of the central duct fan.

It has been recognized before [3] that leaks in central ductwork may produce an increase in the air infiltration rate. To our knowledge, however, the only instance where the effect has been quantified is in a study reported by Prado et al. [5]. A single mobile home with owner-installed flexible ductwork was used in that study. He and his co-workers observed an increase in rate of exchange of air from 0.8 h^{-1} with all HVAC systems off, to values ranging between 2.3 and 2.7 h^{-1} with the HVAC blower operating. There was, perhaps, some doubt that the effect would often be seen in conventional homes with professionally installed central ductwork. Our findings indicate, however, that air leakage in HVAC ductwork is often a major pathway for air and, therefore, energy loss.

The effect of including or excluding the volume of the central duct system from the volume of the house subjected to blower-door pressurization is quite revealing. Exclusion of the ductwork volume causes an average 15% reduction in the specific leakage area. Similar air losses in a duct system have been reported for a California house [6]. Although significant, the magnitude of the effect is much less than the near doubling of the tracer gas air exchange rate brought about by running the central duct fan. A logical explanation is as follows. In a tracer gas measurement with the duct fan running, pressurization of air is greatest within the ductwork and this is especially so in regions close to the duct fan. Such was the case for house #1 with an excess pressure of 25 pascal inside the ductwork. Ductwork leaks thus have a pronounced effect on the overall rate of exchange of air. But the central fan is always turned off for the blower-door pressurization measurements. The pressurization within the ductwork will, therefore, be the same as or even slightly less than in the more open volumes of the house. During the blower-door measurement in house #1, the pressure in the return ductwork was the same as the pressure applied to the living volume. Hence in such a circumstance, ductwork leaks have no preferential influence on the specific leakage area.

Table 1. Rates of air exchange from tracer gas decay.

House No.	Date	Rate of Air Exchange (h^{-1}) central fan off	central fan on
01	14-Mar-83	0.36	0.69
02	09-Sep-82	0.31	0.65
	13-Dec-82	0.48	0.81
24	17-Jan-83	0.96	0.92
	03-Feb-83	0.92	1.04
Mean for 31 houses		0.44	0.78

Table 2. Specific leakage area*

House No.	Date	Specific Leakage Area (cm^2/m^2) Ductwork closed off	vents open
01	15-Dec-83	8.4	10.7
03	19-Aug-82	5.8	6.3
07	18-Aug-82	4.3	4.5
12	19-Aug-82	5.1	5.1
36	25-Aug-82	4.7	4.9
62	15-Dec-83	4.0	5.5
65	15-Dec-83	4.0	4.3
mean for 7 houses		5.1	5.9

*Effective specific leak area at a pressure difference of 4 Pa.

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