Hubs made of spheroidal graphite cast iron possess a relatively high density. This means that the fan is easy to balance, both during manufacture and also later in site.

The ratio of blade to hub weight also makes a significant contribution to assuring a low level of vibrations. The heavier the hub in relation to the blades the less susceptible will the entire fan structure be to residual imbalances in individual blades.

If bearings are welded into a tube and staggered around the axis at points 4 x 90° apart this type of bearing arrangement will have the same rigidity in all directions. A pedestal bearing would result in different levels of rigidity in the various directions and also in different vibration amplitudes (which would be largest in the vertical upward direction).

Summary

The features described will assure maximum performance in fan technology combined with operating economy and operating safety.

However, the described features can only be achieved in close and constructive cooperation between design and planning, the plant manufacturer, the operator and the fan supplier. Also, clear and complete specifications must be demanded by all project participants.

It is one of the most powerful advantages of standards that at a time of accelerating developments with the "electronic years" being measured in a couple of months, NOVENCO clean room fan systems represent the Number 1 choice for any high class clean room in future semiconductor production.

IMPACT OF HVAC OPERATION AND LEAKAGE ON VENTILATION AND INTERCOMPARTMENT TRANSPORT: STUDIES IN A RESEARCH HOUSE AND 39 TENNESSEE VALLEY HOMES*

T. G. Matthews, C. V. Thompson, K. P. Monar, C. S. Dudney and A. R. Hawthorne
Oak Ridge National Laboratory, Oak Ridge, TN, USA 37831

J. P. Harper
Tennessee Valley Authority, Chattanooga, TN, USA 37402-2801

A. B. Williams
Alabama Power Co., Birmingham, AL, USA 35291

Abstract

Forced-air heating, ventilation, and air conditioning (HVAC) systems caused an average and maximum increase in air infiltration rates of 1.8- and 4.3-fold in 42 occupied houses and one unoccupied research house. An average increase in air infiltration rate of 0.33 ± 0.37 h^{-1} corresponds to an air leak of 260 m^3/h, accounting for approximate house volume. Twofold to fourfold increases in air infiltration rates with HVAC operation in the research house were reduced to less than twofold by sealing of the external HVAC unit and crawlspace ductwork system. Such sealing also resulted in a 30% reduction in crawlspace --> indoor transport rates under HVAC on conditions. However, blower door tests indicated a <20% reduction in house leakage area.

Introduction

The ventilation and intercompartment mixing of air in residences strongly influences indoor air quality. Forced-air HVAC systems can impact these pollutant transport processes and resultant pollutant concentrations by (1) large scale mixing of conditioned indoor air, and (2) introducing air through leaks from outdoors and/or unconditioned indoor (e.g., crawlspace or garage) locations. Although HVAC systems typically account for only a small fraction of house leakage area [e.g., 0.14 in 50 homes (1)], twofold increases in air infiltration rates have been observed in 31 homes with forced-air HVAC operation (2). Two studies have been performed to further investigate the impact of HVAC operation on air infiltration rates and inter-house-level mixing processes. Detailed investigations of air infiltration rates and crawlspace <--> indoor transport were conducted before and after sealing the HVAC/ductwork system in an unoccupied research house. Comparison air infiltration rates measurements were also performed under HVAC on and off conditions in 42 residences in the Tennessee Valley.

Experimental Methods

The three-bedroom research house was normally constructed, incorporating a crawlspace and approximately 110 m^2 floor area on a single indoor level.

*Research sponsored jointly by the Tennessee Valley Authority (IAG-40-1602-85), Alabama Power Company (IAG-ERD-85-487), and the U.S.Department of Energy under contract DE-AC05-840R21400 with Martin Marietta Energy Systems, Inc.

Transport of tracer gases between the crawlspace and indoor levels was studied by simultaneously injecting freon into the basement and carbon monoxide (CO) indoors, mixing the gases for < 2 min on each level, and monitoring the rise and/or fall in tracer concentrations on both levels for > 8 h. Air samples were pumped sequentially from four monitoring locations, one in each corner of the house, to a remote instrumented van. Considering a clockwise rotation between sampling points, locations 1 and 3 were indoors, and 2 and 4 were in the crawlspace. Tracer gas concentration data were acquired once per minute for 20 min at each monitoring location. Measurements were performed under HVAC on and off conditions in two sessions, one before and one after sealing the outdoor HVAC unit and crawlspace ductwork systems. Sealing was performed with duct tape and clay, using a blower door and smoke pencils for diagnostics. Blower door leakage area measurements were performed before and after sealing of the HVAC/ductwork system for comparison purposes.

Air infiltration measurements in 42 occupied houses were performed by sequential, 30 min tracer gas decay measurements with the HVAC on and off. Initially, freon was injected into all conditioned compartments on upstairs, downstairs and basement floors (when available) and mixed for about 5-10 min with seven 0.5 m fans and the central air circulation system. The 0.5 m fans were left on during the entire decay experiment to minimize the impact of room-to-room variation in air infiltration rates. The decline in freon concentration was continuously monitored in a central, downstairs location.

Results and Discussion

Consistent with published work (1), the HVAC/ductwork system of the unoccupied research house contributed only slightly to the house leakage area measured in blower door tests (Table 1). Under pressurized testing of 10 to 60 Pascal, an approximate 20% contribution to house leakage area with "leaky" ductwork decreased to near zero levels with sealed ductwork. Interestingly, depressurized testing yielded higher leakage areas overall, but no significant change between "leaky" and "sealed" ductwork conditions.

Table 1: Results of blower door leakage tests in the unoccupied research house

HVAC System	Indoor Duct Openings	Uncalibrated Leakage Area (m^2) Pressurized	Depressurized
"Leaky"	Open[a]	0.31	0.37
"Leaky"	Closed[b]	0.26	0.35
"Sealed"	Open[a]	0.26	0.38
"Sealed"	Closed[b]	0.26	0.36

[a] All exterior windows and doors closed and exhaust fans sealed.
[b] Ductwork vents solidly plugged and taped.

The HVAC operation strongly affected air infiltration rates in the crawlspace and indoor compartments of the research house (Figure 1). With a "leaky" HVAC system, twofold to fourfold increases in air infiltration were observed in both the crawlspace and indoor compartments. After sealing, less than twofold increases in air infiltration were observed indoors, but, interestingly, twofold to fourfold increases persisted in the crawlspace.

Simple, two-compartment, mass-balance models were used to examine the convective transport rate of freon from crawlspace --> indoors and CO from indoor --> crawlspace locations. The models assumed uniform mixing in the crawlspace and indoor compartments, and single source and loss pathways for tracer gas entering and exiting a compartment. The results (Table 2) show interesting and somewhat unclear affects of HVAC operation and HVAC/ductwork sealing. Considering crawlspace --> indoor transport, approximate threefold increases are observed with HVAC operation. Although the $HVAC_{off}$ transport rates remain basically unchanged for "leaky" and "sealed" ductwork (i.e., 11 $\pm$ 1 vs 8 $\pm$ 3 m^3/h), $HVAC_{on}$ transport rates decrease from 33 $\pm$ 1 to 24 $\pm$ 3 m^3/h. In contrast, the indoor --> crawlspace transport rates remain basically unchanged during $HVAC_{on}$ periods and are highly variable during HVAC off periods (e.g., 27 $\pm$ 22 m^3/h), perhaps due to weather effects. Thus, HVAC/ductwork sealing appears to reduce crawlspace --> indoor transport during HVAC operation, but has uncertain impact on indoor --> crawlspace transport.

Table 2: Two compartment modeling of crawlspace-indoor transport rates (m^3/h)

Ductwork	HVAC	Crawlspace --> Indoor	Indoor --> Crawlspace
"leaky"	on	33 $\pm$ 1	26 $\pm$ 3
"leaky"	off	11 $\pm$ 1	27 $\pm$ 22
"sealed"	on	24 $\pm$ 3	27 $\pm$ 5
"sealed"	off	8 $\pm$ 3	2 $\pm$ 0.4

In the 42 occupied houses, the air infiltration rate under HVAC on and off conditions averaged 0.90 $\pm$ 0.54 and 0.56 $\pm$ 0.37, respectively, in the 42 houses. The increase in air infiltration rate with HVAC operation averaged only 0.33 $\pm$ 0.37 h^{-1}. Accounting for conditioned house volume, this corresponds to an air flow of approximately 260 $\pm$ 410 m^3/h. Examining the ratio of air infiltration rates under $HVAC_{on}/HVAC_{off}$ conditions, maximum, average, and minimum ratios of 4.3, 1.8 $\pm$ 0.9, and 0.8 were observed. As expected, the larger 2- to 4.5-fold increases were observed predominantly in the tighter homes, that is, homes with air infiltration rates < 0.5 h^{-1} under HVAC off conditions (Figure 2). For houses with residual air infiltration rates of > 0.5 h^{-1}, 90% of the data ranged from ratios of 0.8 to 2.0.

Conclusions

Proportionately large increases in air infiltration rate occur with forced-air HVAC operation in normally tight houses. Such increases can be reduced with sealing of external HVAC units and ductwork systems. Potential benefits include energy conservation and reduced pollutant (e.g., radon) transport from crawlspace or basement to indoor compartments.

References

1. Caffey, G. E. Residential Air Infiltration, ASHRAE Transactions, Vol. 85, Part 1, p 41 (1979).

2. Gammage, R. B., Hawthorne, A. R. and White, D. A. Parameters Affecting Air Infiltration and Air Tightness in Thirty-One East Tennessee Homes, ASTM STP 904 Measured Air Leakage of Buildings, pp 61-9 (1986).