Air Infiltration Energy Use and Indoor Air Quality – How Are They Related?

David T. Harrje
Princeton University, New Jersey, USA

Niren L. Nagda and Michael D. Koontz
GEOMET Technologies Inc., USA

In recent years there has been a growing trend to reduce energy consumption by tightening the building envelope. Although the practice cuts the use of energy, the resulting reduction in air infiltration rate can adversely affect the quality of indoor air. This is a description of an ongoing investigation of energy and air quality trade offs under way in the United States.

The 2-year study, sponsored by the Electric Power Research Institute (EPRI), focuses on the relationships among residential energy use, air exchange rates, and indoor air quality parameters. The study objective is to develop models to describe these relationships. GEOMET Technologies, Inc., is conducting the study of EPRI in association with Princeton University and Applied Management Sciences.

To meet the study objectives, a specific direction was chosen that enables the investigators to conduct the study under controlled but realistic conditions.[1] The setting consists of two homes (see Figure 1), that are similar to those normally occupied by the general population. These two homes are identical in design and have been built aftar a careful selection of the site so that both are oriented in the same direction with respect to the prevailing winds. One of the two homes (termed the experimental house) has been retrofitted and has an air-to-air heat exchanger. The other home (control house) will remain untreated throughout the study.

Figure 1.
Maryland test site showing experimental and control houses with mobile laboratory.

A mobile laboratory, situated between the houses, allows investigators to monitor both houses for various infiltration, indoor air quality, and energy use parameters. The table below summarizes the on-site measurement system. The measurements will be taken continuously for a period of 12 months. In addition to the continuous measurements, fan pressurization and depressurization measurements are conducted once a month.

The houses will be unoccupied throughout the study. The study is being conducted with a predefined protocol that includes simulation of occupant activities such as use of gas stove, wood stove, shower, washer, and dryer. Thus, duration and mode of operation for any occupant-related activities can be kept constant for the two houses and across different experiments.

The advantages of such a study design are many. The experimental setting allows for comparison of the two houses experiencing the same ambient conditions. Additionally, the controlled conditions and simulated occupant activities will enable the investigators to compare among many different time periods and operating conditions. Thus, for example, pollutant levels generated by a gas stove can be compared under a variety of situations such as between a summer day and a winter day, range exhaust fan 'on' vs 'off', circulation fan 'on' vs 'off', with and without use of the heat exchanger or any combination of these conditions. Similar comparisons will be conducted for other parameters (and effects of interest) for eventual quantification and modelling.

The study is anticipated to answer a variety of questions, including the following:

- How does an air-to-air heat exchanger affect indoor air quality and energy use?
- How does building tightness retrofitting affect energy savings and indoor air quality?
- How do the seasons affect infiltration rates?
- How do climatic conditions affect the mixing of pollutants within the structure and thereby change concentration levels?

Although the experiments will continue for the next several months, some preliminary observations are noted below.

- Over the past 9 months, the variations in air leakage rate for the control house, as measured by the blower door, have remained within 5% of the mean value of 10 air changes per hour at 50 pascals. The seasonal effect on tightness of a building, seen in other investigations,[2] has not been observed to date in this study.
- When the circulation fan is not in operation, the upper and lower levels of both houses – control and experimental – behave like independent zones. This behaviour has an important effect on indoor air quality. For example, if the gas stove is operated when the circulation fan is not operating, the upper level (where the gas stove is located) tends to accumulate pollutants whereas concentrations in the lower level remain low and similar to outdoor levels. However, when the circulation fan is operating, due to either a heating or cooling demand, the whole house behaves as a single zone.
- Although blower door measurements have shown a 40% reduction in the air infiltration rate due to retrofit, preliminary observations indicate that infiltration rates based on tracer gas measurements conducted during the summer have not shown comparable differences. Thus, at least in this situation, seasonal changes have tended to overwhelm the structural differences between the two homes.
- Both houses have repeatedly demonstrated air infiltation rates as low as 0.1 – 0.2 ach under certain weather conditions, demonstrating that air exchange rates can be minimal even without making use of exceptionally tight construction practices.[3]

Table 1. Summary of the measurement system

Measurement Variable	Instrument/Method	Monitoring Zones[a]					Sample Acquisition Mode
		1	2	3	4	5	
1. Air Pollutants							
Carbon monoxide	Nondispersive infrared	x	x	x	x	x	Semicontinuous[b]; two analyzers
Nitrogen dioxide	Chemiluminescence	x	x	x	x	x	Semicontinuous[b]; two analyzers
Carbon dioxide	Nondispersive infrared	x	x	x	x	x	Semicontinuous[b]; one analyzer
Radon	Alpha scintillation	x	x	x	x	x	Continuous; five analyzers
Radon progeny	Gross alpha counting	x	x	x	x	x	Continuous; five analyzers
Formaldehyde	Pararosaniline	x	x	x	x		Integrated; 24-hour sampling
Inhalable particulates	Series filtration	x	x	x	x		Integrated; 24-hour sampling
	Virtual impaction/filtration					x	Integrated; 24-hour sampling
2. Air Exchange							
Sulfur hexafluoride	Gas chromatography	x	x	x	x		Semicontinuous[b]; one analyzer
3. Environment							
Barometric pressure	Aneroid cell					x	Continuous; one instrument
Relative humidity	Hair bundle	x	x	x	x	x	Continuous; five instruments
Temperature[c]	Thermistor	x	x	x	x	x	Continuous; nine sensors
Wind speed/direction	Cup/vane anemometer					x	Continuous; one instrument
Solar radiation	Pyranometer					x	Continuous; one instrument
4. Energy							
Energy consumption	Watt transducer[d]						Continuous; eight transducers
Circuit status[e]	Status tranducer						Continuous; 25 transducers

a Zones 1 through 4 encompass one floor in each of the two houses; zone 5 is outdoors. An 'x' in the column indicates that the particular zone is being monitored.
b Only one or two instruments with a valve sequencer are used to monitor multiple zones. Each zone is monitored once every 15 minutes.
c In addition to 5 zones, the temperatures of the attic and garage in each house are monitored.
d Not zone specific.
e Circuit status is the 'on' or 'off' status recorded for each appliance.

References

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