Title
Houses need to breathe--right?

Author
Sherman, Max H.

Publication Date
2004-10-01

LBNL 54496

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

BERKELEY LAB

Houses Need to Breathe…Right?

M.H. Sherman

**Environmental Energy
Technologies Division**

October 2004

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program, of the U.S. Department of Energy under contract No. DE-AC03-76SF00098.

HOUSES NEED TO BREATHE…RIGHT?

YES, BUT WHAT DOES THAT REALLY MEAN?

MAX H. SHERMAN

Energy Performance of Buildings Group
Indoor Environment Department
Lawrence Berkeley National Laboratory
One Cyclotron Road
Berkeley, CA 94720
October 2004

Sick Building Syndrome. Toxic mold. Asthma. The EPA lists poor indoor air quality (IAQ) as the fourth-largest environmental threat to our country. The American Lung Association notes a link between IAQ and Asthma—the most serious chronic illness of American children.

Outdoor air can remove much of the moisture and other indoor contaminants that cause these problems.

So tight houses are bad, right? Buildings need to breathe, don't they? Well, no. And yes. Tight houses are energy efficient, that's good. But without ventilation they're unhealthy and uncomfortable. And that's bad.

SOLUTION TO POLLUTION IS DILUTION

Houses need ventilation because there are a variety of pollutant sources that would otherwise cause unacceptable levels of contaminants indoors. Volatile Organic Compounds (VOCs), combustion by-products, microbiological components, and particles are all examples of contaminants that are produced indoors and need to be controlled.

The first and often best way to control some types of contaminants is to not let them get into the indoor air in the first place. Toxics and combustion sources can be isolated from the living space. Low-emitting, "Green", products can be used. Spaces where contaminants are necessarily produced, such as kitchens and other "wet rooms", can use ventilation and exhaust fans to get the contaminants out as quickly as possible.

From a practical standpoint, sources will remain even after all reasonable efforts have been made. In principle one could use air cleaning to reduce contaminants even further, but more practically ventilation is required to dilute them. Body odor (or more politely, human bioeffluent) is a good example where ventilation is the best strategy.

BUILDING SERVICES ARE NOT FREE

Like virtually every other service that a home provides, there is an operating cost associated with providing acceptable indoor air quality. This cost is principally the cost of conditioning the air used for ventilation, but it also includes the costs of any equipment needed to provide ventilation must be included as well.

Conditioning the air means making it acceptable in a variety of ways. The air may have to be heated in a cold climate, cooled in a hot climate, filtered in a dirty climate, or dehumidified in a humid climate.

The trick is to find the ventilation system that provides acceptable indoor air quality in the best way possible. To find the best system, one needs to understand minimum ventilation requirements, climate, and the interactions with the building as a whole.

WINDOWS AND LEAKY HOUSES ARE NOT THE ANSWER

So we need ventilation. Can't we get it from windows? No, at least not reliably. People are particularly bad at sensing when and how much to open the window. Also, there are a bunch of other reasons why people don't want to their open windows: comfort, noise, security and dirt.

What about leaky walls, aren't houses too tight nowadays? Infiltration (leaky walls) is a very robust ventilating method—it works even when the power fails. A typical house is leaky enough to meet minimum ventilation requirements three times over. So no problem, right?

Well, No. There may be no IAQ problem, but that's a pretty bad way to ventilate. All of those drafts are uncomfortable and unnecessary. The average (existing) house in this country has about three square feet of holes in its shell. You could plaster the holes with twenty dollar bills and, in terms of energy saved, it would pay for itself in a year Building a home with large, random leaks isn't a great idea for either comfort or energy reasons.

Because infiltration is a strong function of weather, there are few climates in which infiltration is a good primary ventilation approach. A hole that gave just the right amount of ventilation during mild periods would way over-ventilate when energy and comfort mattered the most. A holes sized for more severe weather would not provide enough ventilation during mild weather.

Sure enough houses have gotten much tighter in the last decade or so. These results suggest that the use of air barriers, gaskets, caulking and other sealing methods is probably sufficient. This trend seems equally true in both conventional construction and construction taking part in energy efficiency programs, such as Energy Star.

Because new houses are about four times tighter than older ones, they're more energy efficient and more comfortable, but they are under ventilated. Infiltration alone can no longer supply enough fresh air. Now, more than ever, it's important to consider ventilation design.

SO HOW TIGHT ARE NEW HOUSES?

People measure the tightness of new houses for a variety of reasons. We have gathered up many of these measurements[1] to try to get an indication of how tight new houses are and how this has changed over the last few years. The plot below is a summary of the measurements we have collected on houses built between 1993 and 2000;

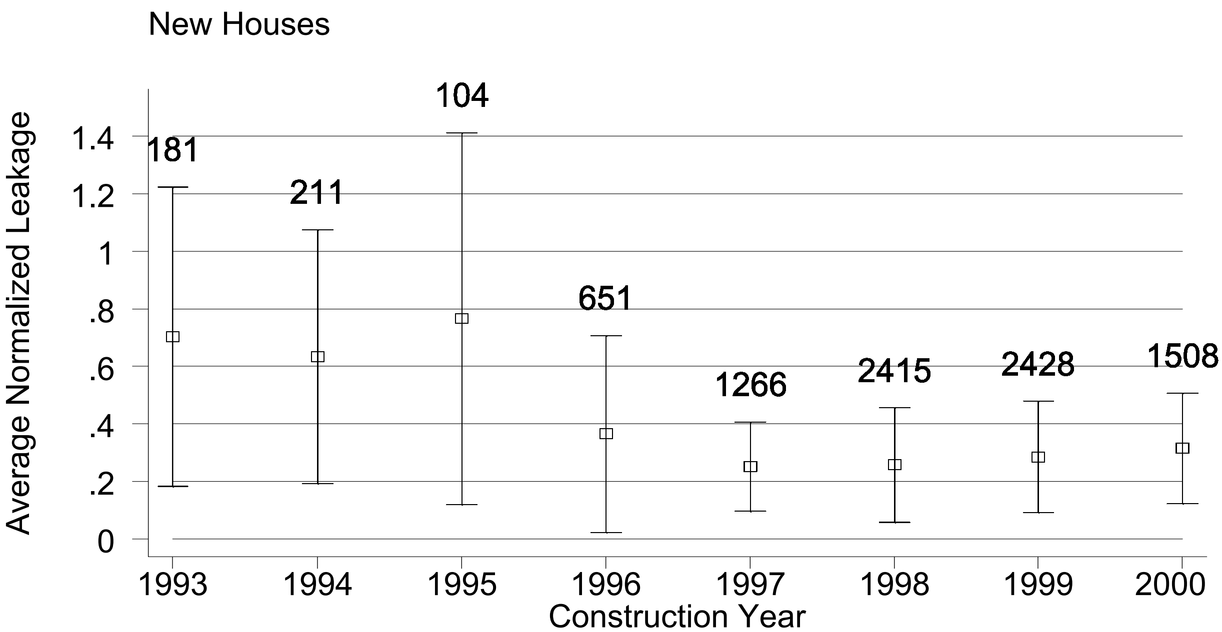

FIGURE CAPTION: Normalized Leakage for new houses by year of construction. Size of bars indicates the standard deviation of the sample for each year. Numbers above bars indicate sample size

The plot is the normalized leakage vs. year of construction. Normalized leakage is a measure of tightness but, as a rule of thumb, it is a rough estimate of the seasonal infiltration rate. This plot suggests that until the mid-90s houses were getting tighter, but that trend has stopped.

The data suggests that most new houses are not going to be sufficiently ventilated by infiltration and thus need some kind of ventilation system, but the infiltration itself is not so small as to be ignored.

[1] *Sherman, M.H. and Matson, N.E.,* **"Air Tightness of New U.S. Houses: A Preliminary Report"**, Lawrence Berkeley National Laboratory, LBNL-48671, 2002.

An interesting fact not shown in this plot is that there was no substantial difference, on average, between those homes that self-identified themselves as "energy efficient" (e.g. Energy Star©) compared to those that were "conventional".

These results suggest that the use of air barriers, gaskets, caulking and other sealing methods in the better conventional houses is ply at a sufficient level of quality for ventilation-related purposes. (One might need substantially tighter constructions to protect walls from water intrusion or reduce drafts in severe climates, for example.)

BUILD TIGHT, VENTILATE RIGHT

A tight house means no more relying on leaks to do your dirty work for you. You need to actually give some thought to the ventilation design.

In principle, one could design a home with passive stacks, wind traps, variable inlets, and a host of other passive features that would provide the right amount of ventilation throughout the year. Such an architectural solution would be sustainable, but would be quite difficult to achieve in today's world where the microenvironment around the building could change and where the economic environment may not allow for individual, custom designs.

So, the most practical solution is often going to be to put in some sort of mechanical ventilation system. While source control and local exhaust needs are pretty much the same in every region, the optimal whole-house mechanical ventilation system will depend on climate. Selection of a whole-house ventilation system depends on a variety of details, but there are some conventional starting points.

The ventilation system to compare all others against is the simple continuously operating, exhaust fan. Such a fan can be stand-alone or do double duty by taking the place of a bath fan. With the quiet, energy-efficient fans currently available such an option is cheap and easy.

In areas in which heating costs are high, a heat pump can be coupled to the exhaust air stream to perform heat recovery either for water heating or space heating.

Some people have concerns that exhaust fans cause excessive depressurization, which could interfere with combustion equipment or pull in soil gas. While excessive exhaust can cause such problems, it is not whole-house systems that you need to worry about. The rates needed for this kind of ventilation are smaller than a typical dryer and much smaller than some of the large kitchen exhaust fans being installed in new houses.

Some people have concerns that depressurization could cause moisture incursions into walls in hot, humid climates. To reduce worries in these climates supply ventilation systems can be used.

A supply system could have a dedicated supply fan, but then would need to deal with distribution and also tempering. Accordingly, the most common implementation of a supply system uses an intake into the return plenum so that outdoor air is pulled into the house through air handler whenever it operates.

Such a supply air intake must have a control system to make sure it operates enough to supply minimum rates. It also should have a controllable damper on it to makes sure it does not over-ventilate. Without these controls, this system just becomes a hole in the return duct and is worse than infiltration.

One can also consider adding a heat pump to pre-cool the supply air and use the heat to heat water as a means of saving energy. A carefully designed system can be especially valuable in a hot, humid climate because it can provide dehumidification.

In extreme (hot or cold) climates balanced ventilation with a heat or energy recovery ventilator can be preferred. These systems temper the incoming air as well as reduce the energy impact. Balanced systems, however, require a significantly tighter building shell to work well.

All the above systems for reducing energy impacts increase initial cost and require increased maintenance, so a life-cycle analysis should be used to optimize the result.

VENTILATION CAN'T SOLVE ALL IAQ PROBLEMS

Ventilation is good at diluting internally produced gaseous compounds such as those from people or from building materials. But for some contaminants, ventilation is not terribly effective and can even be counter productive.

When there are contaminants in the immediate vicinity of the house, such as pesticides or radon, ventilation can bring them indoors. Large particles, whether they be generated indoors or out, are another example.

Since small particles (such as combustion byproducts) can act like gasses in that they mix quickly in the air and follow air currents. Accordingly, ventilation works well to control them.

But like footballs and hockey pucks, pollen, pet dander, and dust particles don't stay airborne very long. Ventilation isn't effective at removing or diluting them. These large particles can be kicked up over and over again to bother occupants, so the best source control approach is cleaning, not ventilating.

To make matters worse, some large particles slowly emit semi-volatile organic compounds (SVOC) into the air. One example is being in a room where people have been smoking. Some of the combustion byproducts continue to emit odorous compounds long after they've landed. These compounds can be ventilated away, but the best way to control them is cleaning.

Finally it is important to make sure that the ventilation system itself does not directly or indirectly become a source of contamination. If particles are allowed to build up in ventilation systems or if indoor humidity is not controlled, the process of ventilation could create a bigger problem than it solves. Such considerations must be part of a whole-house design.

"HOUSTON, WE HAVE A PROBLEM."

On of the biggest complaints heard against the use of mechanical ventilation in homes comes from those in hot, humid climates who are, quite rightly, concerned about the impact of drawing hot, humid air into air conditioned spaces. If enough moisture is allowed to condense in the wrong place, mold problems will develop.

So the questions are: how much moisture and where does it go. Not ventilating would remove some of that moisture problem, but it would create unacceptable indoor air quality for other reasons. The issue then becomes one of design choices that make sure that moisture is taken care of. In a hot, humid climate you can have a cubic foot of water per day from the ventilation air. When combined with internally generated moisture sources, this can be too much.

To deal with it you need to consider or combine three design options:

Tolerate: You can accept periods of high moisture levels, if the materials and constructions are chosen to be moisture tolerant. Hard, cleanable surfaces for example, may be better design choices than fuzzier ones that could encourage mold growth.

Desiccate: Get the extra moisture out of the air by condensing it and draining it. Air conditioners can remove moisture, but they are normally sized and designed for controlling temperature. In some climates, especially in well-built houses with low thermal losses, they cannot supply enough dehumidification as normally used. Other options include stand-alone dehumidifiers and equipment that can vary the amount of moisture extraction.

Procrastinate: In some climates there are sufficient periods where the humidity becomes low. In such cases it may be possible to use hygroscopic materials that store moisture during the hot, humid periods and then release it during the dry ones. There is more to say on how to do this, but that is for another day.

Just as we learned that stuffing more insulation into attics can cause moisture problems, if you do not consider the system as a whole, so will stuffing more outdoor air into a home. Simply adding extra moist air into a home in a hot, humid climate will significantly increase the probability of moisture-related problems, unless some thought is given to moisture management at the whole-house level.

"WHERE'S THAT ROLL OF DUCT TAPE, TOM?"

There are legitimate reasons for temporarily lowering ventilation rates and these usually center around the poor outdoor air quality or other transient outdoor air problems[2]. Examples of this could include smoggy afternoons or when your neighbors are spraying their trees or there is a outdoor exposure that is dangerous.

Ventilation systems that pull air into the house through small holes (e.g. exhaust systems) can be particularly effective at reducing indoor ozone exposures from smog, because ozone is quite reactive and will decompose more quickly coming into contact with surfaces.

Good particle filtration can reduce exposure to a variety of outdoor contaminants from soot to pollen.

A tight house and a mechanical ventilation system can give an occupant a lot of flexibility in responding to outdoor air incidents. If the air inside the house is normally exchanged with outdoor air, it represents a pool of air that can be used to allow a home to float through a few hours of bad outdoor air quality.

For extreme situations like pipeline explosions, toxic fires, or terrorist attacks this principle can be extended to create "Safe Havens" inside the home.

ASHRAE 62.2: RESIDENTIAL VENTILATION STANDARD

In 1631 King Charles passed the first ventilation code. Not much has changed since then, until now. ASHRAE Standard 62.2[3] takes a giant step forward.

In 1996 ASHRAE recognized that there was a need to have a separate standard for residential ventilation and formed a committee to do just that. Seven years later ASHRAE approved Standard 62.2-2003. As a standard intended for use in regulation, 62.2 was crafted to be the minimum requirements necessary to provide minimally acceptable indoor air quality for typical situations. The standard is a trade-off between dilution ventilation and source control and attempts to be as flexible as the consensus process allows.

In developing this standard, the committee recognized that there were many different kinds of houses, climates, and styles of construction. To accommodate these differences, the major requirements have several alternatives which allow users some flexibility. Some requirements are performance based, with specific prescriptive alternatives. The standard recognizes that there are several different ways to achieve a specified ventilation rate and allows both mechanical and natural methods.

62.2 is not an overly complex or long document. It is applicable to both new and existing homes including all single-family homes and small multifamily ones. Its major requirements are listed below:

---

[2] *Sherman, M. H. and Matson, N. E.* **"Reducing Indoor Residential Exposures to Outdoor Pollutants"** LBNL-51758

[3] *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings* is a standard by the American Society of Heating Refrigerating and Air Conditioning Engineers (2003) http://www.ashrae.org

With some exceptions, the standard requires whole-house mechanical ventilation. For a typical house the value is about 50 cfm, but it varies by house size. The standard provides guidance for and allows great flexibility in ventilation systems selection: continuous or intermittent; supply or exhaust; with or without heat recovery; etc.

- Mechanical exhaust (i.e. to outdoors) is required in kitchens. The basic requirement is for a user-operable vented range hood of at least 100 cfm. To accommodate the wide range of kitchen configurations in the market, the standard includes an alternative of 5 (kitchen) air changes per hour of (continuous or intermittent) exhaust without any requirements regarding location within the kitchen.

- Mechanical exhaust is required in bathrooms, but not in toilets, laundry rooms, lavatories, utility rooms, etc. The basic requirement is for a user-operable fan of at least 50 cfm. A continuously operating exhaust fan of 20 cfm may be used as an alternative.

- The fans required to meet the previous requirements must demonstrate specific air flow and noise performance levels.

- Combustion appliances must follow applicable codes. For a narrow set of circumstances, vented combustion equipment must be checked for backdrafting. Otherwise there are no requirements specific to combustion equipment, vented or unvented.

- When air handlers or return ducts are in an attached garage, the duct system must be tested for air tightness.

- Good particle filtration is required upstream of air handling components.

There are a few other requirements, which are either minor, codify general practice, or are relevant only to specific situations.

CONCLUSION

Houses need to breathe, but we can no longer leave the important functions associated with ventilation to be met accidentally. A designed ventilation system must be considered as much a part of a home as its heating system. Windows are a key part of that system because they allow a quick increase in ventilation for unusual events, but neither they nor a leaky building shell can be counted on to provide minimum levels.