TIGHTEN UP YOUR ADVICE ABOUT AIR SEALING

A green building program manager has found that combining prescriptive and performance standards yields better air sealing practices.

BY MARK NEWEY


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Air sealing is a basic prerequisite for high-performance construction. A well-sealed house will be more comfortable, will have improved indoor air quality, and will reduce the homeowner's utility bills. At the Southface Energy Institute, where I am program manager, we promote airtight construction, as do many other building science organizations. This article presents some of the lessons I've learned as a manager and inspector for builders and subcontractors in several energy efficiency programs, including EarthCraft House, Right Choice, and Home Performance with Energy Star (see "Three Performance Programs," p. 42).

Setting the Standard

There are two methods to set the standard for achieving a tight building envelope: prescriptive standards and performance standards. Prescriptive standards include air sealing measures, such as "seal all window and door rough openings." Performance standards are usually based on empirical data, such as blower door test results. At first glance, performance standards seem like the obvious choice for measuring the effectiveness of air sealing—but if a builder is not taught how to construct a tight envelope, setting a performance standard can lead to undesirable results.

For example, one of the builders we have worked with set a blower door standard of 0.35 ACH_{nat} for every home. (One-third of the volume of the home exchanges with outside air every hour under natural conditions.) Some air sealing was completed before the wall insulation was installed, but when the home was blower door tested, the home would fail and the builder would run around the house with a can of spray foam and fill in locations where air was leaking through the building envelope.

The builder had missed important details, such as plumbing penetrations, washer/dryer hookups, and the intersection of the bottom plate and the subfloor. After several hours of running the blower door and using spray foam, the house would finally reach the testing goal—but what a costly investment of time!

The builder assumed that the insulation contractor would take responsibility for the test result. The insulation contractor, however, while he played a large role in air sealing the home, did not want to guarantee the results because some air sealing was outside the scope of his work. A tight building envelope results from the combined efforts of a number of contractors, and most production builders prefer a defined list of actions rather than a performance standard. Also, most performance standards allow modest air leakage, and if all of this leakage is concentrated in one or two areas, comfort

or performance can be compromised.

The other side of the coin is a prescriptive standard. The drawback here is that a prescriptive standard tends to oversimplify air sealing. A prescriptive standard is unlikely to specify, for example, "Seal plumbing penetrations in floor joist between vented crawlspace and conditioned basement," unless the list of tasks is extremely long! There's no way air sealing can be described comprehensively in a list of tasks.

Lengthy prescriptive language can be just as bad as having no standard at all. Builders will draw the wrong conclusion: "I've done my job if I do everything it says."

How does the energy code instruct builders to air seal? The 2000 International Energy Conservation Code states that "exterior joints, seams or penetrations in the building envelope that are sources of air leakage, shall be sealed with durable caulking materials" (Section 502.1.4.2). The language is unspecific and doesn't describe nuances of effective sealing. Certainly this statement cannot be used as a tool to instruct builders.

In the original EarthCraft House standard (created in 1999), builders were given the choice of using a prescriptive or a performance standard. They could score points for each air sealing measure that they completed, or they could score points for achieving a good blower door result. Unfortunately, builders would get the house blower door tested, and if it didn't pass they would claim that they had done a bunch of air sealing measures and would try to take credit for them.

If they had done the air sealing, the house would have done better on the blower door test, but since the EarthCraft House program has only a single inspection at the completion of construction, it was impossible to verify that air sealing measures were actually completed. The current EarthCraft House standard and the Right Choice standard require that builders complete both a set of prescriptive air sealing measures and a blower door test. Since we have started using this combination of standards, blower door results have improved.

It is a good idea to match the strictness of your prescriptive standards to the tightness of your performance standards. If you require every seam in the sheathing and drywall to be sealed and then have a fairly loose performance standard, builders begin to wonder why they are spending so much time sealing things that are "unnecessary." Conversely, setting very few prescriptive standards and having a tight performance standard frustrates builders and makes them wonder why you are making them work so hard.

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Mark Newey (right) talks with contractors during training for Home Performance with Energy Star.

It's critical to normalize the blower door test results so that a performance standard applies to homes of different sizes at different locations. Prior to 2004, almost all of Southface's blower door test results were converted to ACH_{nat}, using Lawrence Berkeley Laboratory (LBNL)'s equation of $ACH_{nat} = CFM_{50} \times 60 / (N \times volume)$, where N = C (climate factor) x H (height factor) x S (shielding factor).

The benefit to ACH_{nat} is that most people can conceptualize 1 ACH: "In one hour, an amount of air equal to the entire volume of air in this house is replaced by outside air." There are two major drawbacks to this method. First, the C, H, and S factors are subjective and can result in different CFM_{50} goals for the same house, depending on the calculation of N. Second, the ACH_{nat} metric results in lower air infiltration for homes with larger volumes, because volume increases exponentially with increasing surface area.

This year Southface changed to a different metric: All new homes must meet a leakage ratio defined as the volume of air flow at 50 Pa (CFM_{50}) divided by the square footage of the building envelope (sfbe). This has proven to be fairer for all sizes of homes, although describing the standard to builders can be difficult. Existing-home programs should use ACH_{nat} because it's easier to explain to homeowners who want to know why they should spend money on air sealing.

How tight should the blower door test goal be set? This depends on your overall strategy for promoting high-performance construction. In the Greater Atlanta area, the housing market is booming, and builders feel they can sell any house regardless of its energy efficiency. These builders find it difficult to substantiate any added costs—especially detailed air sealing, which may cost a few hundred dollars. A blower door test result of a typical production home in Atlanta measures 0.6 CFM_{50}/sfbe, so we set a standard of 0.4 CFM_{50}/sfbe—a standard that is attainable for most builders.

The goal essentially becomes stricter as builders' experience with the program grows. In the EarthCraft House program, builders must attain a minimum of 0.4 CFM_{50}/sfbe but are awarded points for achieving 0.25 CFM_{50}/sfbe. At first it's difficult, but they discover what works and what doesn't and the blower door test results improve.

Training the Contractors

Once a standard has been developed for a builder, the people involved need to be taught how to accomplish the goal. Formal training can take place in the classroom or in the field. There are benefits to training in either location. At Southface, we have found that classroom training is a critical first step to give construction professionals a conceptual understanding of the whole house. While they may likely forget some of the details, a good

trainer will reinforce key concepts, and they'll walk away with better understanding.

Since the instruction is conceptual, it is often possible to train many different types of professional at the same time. We train builders, HVAC contractors, and insulation contractors together. Training professionals in a single field is generally better. Training groups with different needs can be a disaster. We once trained builders and realtors together. Evaluations said either "Too short, not enough detail" (typical builder response) or "Too long, too much detail" (typical realtor response).

Some of the primary concepts we cover in our classroom training include the impact of air infiltration on energy consumption, on equipment sizing, and on IAQ. We always make sure to debunk the myth that you can build a house too tight. Another goal is to emphasize that air sealing is required by

THREE PERFORMANCE PROGRAMS

Several energy efficiency programs that I've been involved with, including the three programs described below, have taught me some valuable lessons in program management.

EarthCraft House

EarthCraft House is the Southeast's largest green building program. The program began in 1999 as a partnership between Southface and the Greater Atlanta Home Builders Association; it is available to builders in Georgia, South Carolina, and Alabama. The 75 active builders in the program build about 1,200 EarthCraft homes per year. To qualify as an EarthCraft House, a home must score at least 150 points on a worksheet that covers 12 different categories, including energy efficiency, indoor air quality (IAQ), water conservation, site planning, and resource-efficient building materials. Every home in the program receives a final inspection, which includes a blower door test and a duct blaster test. Read about the program at www.earthcrafthouse.org.

Right Choice

Right Choice is a utility rebate program for builders in the Jackson Electric Membership Corporation service area in northeast Georgia. This program began in early 2004. There are about 100 active builders in the program, building about 600 Right Choice homes per year. To qualify as a Right Choice home, a house must meet a specific set of program standards, including comprehensive air sealing, improved insulation levels that surpass the International Energy Conservation Code (IECC) 2000 energy code, and properly installed ductwork that does not restrict air flow. Southface provides a room-by-room load calculation for every home, and every home is inspected twice: before drywall and at the end of construction. Diagnostic testing is performed on every home; it includes duct blaster, blower door, and flow hood testing. Right Choice air sealing standards are as follows:

- Chases must be capped.
- Solid sheet must be installed behind tubs and showers on insulated walls.
- Attic kneewalls must be sheathed.
- Stud cavities must be blocked from attic. Blocking or top plate will be needed at change in ceiling height and attic kneewalls.
- Joist cavities under attic kneewalls must be blocked.
- Top and bottom plate penetrations must be sealed.
- Bottom plate must be sealed to poured wall, slab, or subfloor.
- Penetrations in exterior wall sheathing must be sealed.
- Window and door rough openings must be sealed (not chinked with insulation).
- Gaps greater than $^1/_8$ inch between pieces of exterior sheathing must be sealed.
- Exhaust fan penetrations must be sealed at band joist.
- Exterior outlets and exterior light fixtures must be sealed at the wall sheathing.
- Exterior walls of fireplace chase must be sealed (including at combustion air inlet).
- Penetrations through insulated subfloor must be sealed.
- Shower and tub drains must be sealed (rock wool and fiberglass are not acceptable).
- HVAC boots in insulated floors must be sealed to subfloor.
- Soffits must be sealed at cantilevered floors.
- Gaps in chase caps and blocking must be sealed.
- Recessed can lights in insulated ceilings must be airtight.
- Ceiling-mounted electrical fixtures, including lights, ceiling fans, and speakers in insulated ceilings, must be sealed to drywall.
- HVAC boots in insulated ceilings must be sealed to drywall.
- Attic kneewall doors must seal tight—this requires weatherstripping and a latch.
- Attic scuttle holes must seal tight—this requires weatherstripping.
- Attic pulldown stairs located in conditioned space must seal tight—a sealed cover box with weatherstripping is recommended.
- Exterior doors must have weatherstripping and thresholds. This includes all doors that penetrate the building envelope, which may include the door between the house and the basement.
- All homes must pass a blower door test with a result of 0.4 CFM/sfbe or less.

See more at www.jacksonemc.com.

Home Performance with Energy Star

Home Performance with Energy Star is DOE's and EPA's existing-home program. Southface has been developing the Atlanta-based pilot of the program, which began in late 2004. Participating contractors learn to assess existing homes for opportunities to improve energy efficiency, IAQ, and water conservation. A contractor assesses every home with a blower door test and either a duct blaster or a flow hood test. Southface audits the work of contractors to ensure that their assessments and improvements are consistent with sound building science practices. See more at www.southface.org.

the energy code. (Leaning on the energy code too heavily can be ineffective, because builders know they can build leaky homes and get away with it.)

In our training, we help the builder to categorize air sealing based on the sequence of construction. Southface divides air sealing into three areas: blocking and sheathing, predrywall air sealing, and postdrywall air sealing. This is critical, because some builders think of air sealing as something that the insulation contractor does just before installing wall insulation. While that is one part of air sealing, it is not the whole picture.

Builders with the tightest homes recognize that all contractors—including HVAC, insulation, and drywall trades—play a role in the air sealing process. Framers contribute by sheathing attic kneewalls, capping chases, and blocking cavities between conditioned and unconditioned spaces. HVAC contractors contribute by recognizing ductwork that penetrates the building envelope and sealing appropriately. Drywall contractors contribute by completely finishing mechanical rooms, garages, and other nonliving spaces adjacent to the conditioned space, as well as by using drywall glue or gaskets appropriately.

Code officials can be allies in the promotion of high-performance construction if they are included in the training process. Southface has had the good fortune to partner with state energy offices throughout the Southeast to offer energy code training to code officials. Code officials in most jurisdictions appreciate practical energy code inspection guidelines, since the code language tends to be confusing.

In Georgia, the Department of Community Affairs adopted Southface's air sealing diagrams as a supplement to the energy code (see Figure 1). In the two years since these graphics were added to the code, air sealing enforcement by code officials has improved. In some jurisdictions, code officials now require air sealing to be complete at the rough inspection before insulation and drywall.

Field training is critical for the people who will be doing the actual air sealing and for those who will be checking the work. This includes crew leaders, site superintendents, the builder's inspectors, and the warranty department. This training needs to be short, entertaining, and hands-on.

One format that works well is to walk through a framed house to identify potential gaps in the building envelope and then go to a similar finished house to run a blower door test and see where the air ends up coming in. We find that scouting the houses ahead of time is helpful, to avoid being surprised by the results!

Builders retain information lots better when you show them just a few examples of failures in the homes they have built. A light-hearted approach I learned from a Building America partner is to start a dialogue like this: "If I put my hand here, it's inside the envelope. If I put it here, it's outside the envelope. Simple enough. Now if I put my hand here, where is it—inside or outside?"

Often, the most difficult concept for contractors is defining the building envelope. Many homes do poorly because the building envelope is never completed—and not because of a few small holes or cracks. For example, a builder who is focused on sealing the wall sheathing easily overlooks bypasses under attic kneewalls. A tight home requires a builder to watch for air sealing opportunities throughout the entire construction process.

Don't underestimate the power of informal conversations in the training process. A conversation in a basement with a builder trying to figure out the best approach to sealing a combustion closet can have more impact than the best classroom training. In our Home Performance with Energy Star program, we require that contractors bring us along on at least three existing-home assessments to maximize the opportunity for this sort of informal training. Contractors who do their own blower door testing need to be taught how to

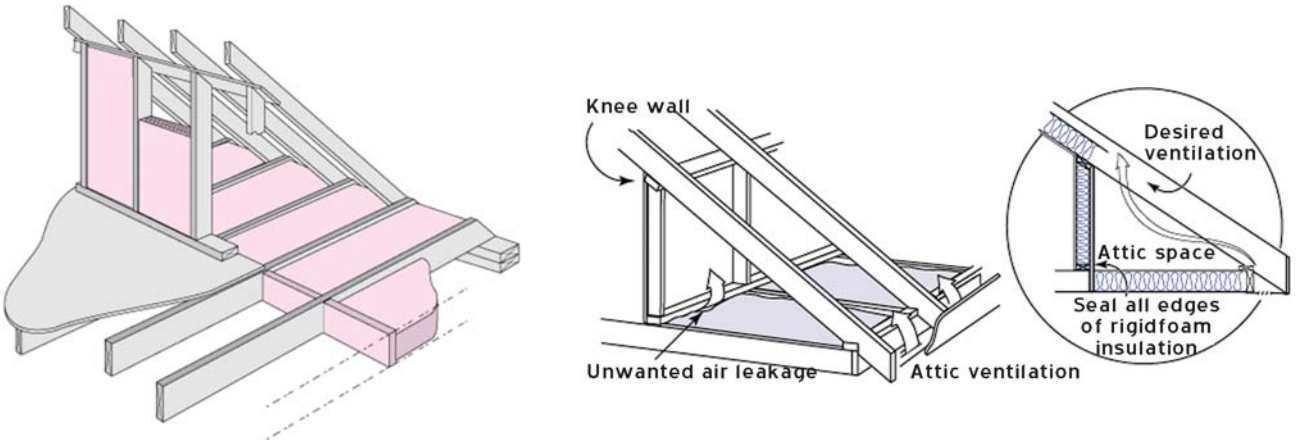

Figure 1. Ever since these air sealing diagrams were added to the Georgia energy code, air sealing enforcement has improved.

interpret the results and how to find the leaks.

Field Verification

Inspecting homes for air sealing must be done in a thorough, consistent, and fair manner. A plan for resolving air sealing problems must be in place—and remember that timing is critical.

In the Right Choice program, we inspect every house just before the wall insulation is installed. At the time of the inspection, all blocking and sheathing must be installed and all wall sheathing sealed; top and bottom plates must be sealed, and the subfloor must be completed. This represents a bit of an inconvenience for the builders, since they are anxious to hang drywall and finish their houses, but it allows us to ensure the quality and consistency of air sealing.

Typically the insulation contractor makes three trips to each house in this program: one to air seal the walls and floor, another to insulate walls and other enclosed cavities, and a third to air seal and insulate the attic. Our technicians use a concise inspection form to check air sealing, and every technician is equipped with a can of spray paint to mark any areas that have not been fully sealed. When the insulation contractor returns to put insulation in the walls, they can easily find any gaps, cracks, or seams.

Spray painting holes is more effective than making written lists. This is because it is difficult to describe where holes are located, because the person doing the air sealing will probably never see the list, and because most of our technicians speak only English, while most of the air sealers speak Spanish.

Inspections after drywall can include checking for proper air sealing between the house and attic or between the house and garage. The blower door is a perfect tool for checking for air leakage. Simply turn it on, leave it running, and walk around the house to feel for air leaks. If a preinsulation air sealing check was performed, the house almost always passes the blower door test.

EarthCraft House requires a single final inspection after drywall, so finding air leak sources can be challenging. Air will move through a recessed can light above the kitchen as the result of an unsealed band joist on a two-story home. In some situations, such as leaks between the house and the garage, reversing the blower door and pressurizing the house can help pinpoint the leak pathway, since the technician can walk around the garage and feel for leaks there. Without a rebate or other financial incentive, most builders won't pay for a preinsulation inspection, though such an inspection would prevent air sealing problems from coming up later.

Strive to create a relationship where the builder views the inspector as a quality assurance partner and not as a regulatory code official. Good relationships with builders make the long-term difference. Every inspection becomes an opportunity to educate the builder. A good relationship begins with clear communication. (Don't be the energy cop.) Set air sealing goals, discuss common techniques, and explain testing protocol. Promote successful relationships by having the same inspector do all of the inspections for one builder.

We have found that it is absolutely critical that our field staff have solid building science knowledge and good communication skills, so that they can provide specific advice to builders. A well-spoken response to a builder's question about energy code requirements can build trust between builder and inspector. When we fail to train our inspectors properly, our failure usually comes back to haunt us.

Blower door testing provides the evidence that homes are airtight. (Builders may even get excited when they do

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Howard Katzman, Southface's technical project manager, conducts field training for Home Performance with Energy Star.