Controlling Air Leakage

These simple techniques save energy in new construction

by Jim Maloney

Many builders still assume that careful air-sealing techniques are only for the lunatic fringe of construction-the folks who build houses so tightly that the homeowners can't take a deep breath without sucking smoke back down the chimney. That's too bad. Uncontrolled air leakage in a home not only affects the annual heating and cooling bills but also the effectiveness of ventilation systems and the long-term durability of the structure (see sidebar facing page).

Sealing a house carefully doesn't call for exotic techniques or an extra bank credit line. With a caulk gun, a razor knife, a systematic approach and $250 or so, you can eliminate most air leaks and improve the energy efficiency of any new house. The systematic approach is called the Simple Caulk and Seal (SCS) system. It was devised several years ago to address complaints from builders that other tightening schemes were too complicated. The system helps builders identify potential air leaks before construction starts and offers techniques to seal them. The idea is to make the process so simple that there's really no reason not to seal a house carefully.

Here's a summary of how it works. First, a builder uses a checklist and a set of building plans to identify potential air leaks. Then the builder works out a strategy for sealing the potential leaks and figures out who should do the work (it might be any of the trades). Snooping out potential leaks isn't as tough as it sounds, though. That's because the floor sheathing and the drywall ceiling/wall surfaces provide 90% of the air barrier. Careful caulking and sealing generally plugs any other potential leaks.

Why houses leak—There are two natural forces that cause air to move into and out of buildings: the stack effect and the wind. The stack effect causes most of the uncontrolled air exchange. It occurs when there's a wintertime temperature difference between the air inside a home and the air outside. The difference in air densities causes cold outside air to infiltrate at the lower levels of a home while the wanner inside air exfiltrates at the upper levels.

Wind forces operate as you might think. Infiltration occurs on the windward (positive-pressure) side of a home when cold air is forced *into* gaps in the building shell. Exfiltration occurs on the leeward (negative-pressure) side of the house when warm air is sucked *out of* gaps in the building shell. Wind effects on air exchange vary with shielding and terrain conditions at the site. However, a home on an exposed site may have wind-induced infiltration three or four times as large as in a more protected site.

SIMPLE*CS — **AIR SEALING CHECKLIST** — 1

JOB/HOUSE: SAMPLE

ADDRESS: 2345 FRONT Street

GENERAL NOTES:
(1) Caulk at fire blocking during drywall.
(2) Block and caulk around tub/shower assembly.
(3) Use weather-stripping.

GROUP A MAJOR STRUCTURAL OPENINGS OR COMPLICATIONS	CHECK IF THIS APPLIES	TIMING: DURING INSTAL.	TIMING: BEFORE INSUL.	TIMING: AFTER DRYWALL	TIMING: OTHER	TYPE OF SEALANT: CAULK	TYPE OF SEALANT: GASKET	TYPE OF SEALANT: FOAM	TYPE OF SEALANT: ADHES	TYPE OF SEALANT: SHEET	TYPE OF SEALANT: OTHER	WHO DOES SEALING WORK?
Doors (swinging and sliding) in ext. walls	✓			X		X						FC
Windows in exterior walls	✓			X		X						FC
Skylight assemblies in roof/ceiling												
Attic access hatch cover(s)	✓			X							X (3)	FW
Crawlspace access hatch covers												
Other openings to unheated spaces (storage, etc.)												
Dropped ceilings in kitchens, baths, family rooms, etc.												
Soffitt assemblies that intersect ext. ealls or ceilings												
Furred spaces for plumbing, ductwork, chimneys, etc.												
Stairways in contact with ext. walls or unheated spaces	✓				(1)	X	X					Drywall Sub.
Bathtubs or tub/showers at ext. walls and floors	✓				(2)	X				X		FW
Pocket doors in walls intersecting ext. ceilings	✓	X				X						FC
Fireplaces on exterior walls (metal or masonry)												
Masonry hearths penetrating to crawlspace or basement												
Electrical panel in exterior wall	✓			X		X						FW

A systematic approach. **A checklist like the one above should be filled out prior to construction and given to all tradesmen—in this example, the drywall subcontractor, the finish carpenter (FC) and the finish worker (FW), or whoever handles the punch list.**

Because it's difficult to control the stack effect and the wind, the only effective way to reduce their impact is to minimize the number of holes through which air can flow.

Earlier approaches—In the early 1980s, builders began experimenting with various techniques to limit air leaks. One technique was the continuous polyethylene air-vapor barrier (PAVB). It was adapted from the Canadian R-2000 building program and from similar techniques used in factory-built houses in Sweden. The approach consisted of installing a continuous layer of poly over the inside surface of the building's exterior shell. Polyethylene was chosen because it could stop air leakage and reduce vapor diffusion.

A number of builders had success with this approach, but many found it too complicated because the detailing had to be handled very carefully. In factory homes the PAVB system was more effective because it could be installed under tightly controlled and predictable conditions.

In the mid-1980s, a technique that would eventually be known as the advanced drywall approach (ADA) was promoted as a more realistic alternative to PAVB. The ADA approach used faced insulation, foil-backed drywall or vapor-retarder paint as the diffusion retarder. The air barrier was provided by the drywall and the plywood subfloor, as long as the junctures between them were sealed with a compressible gasket. But ADA wasn't without problems. It also required an attention to detail that wasn't always possible on the job site.

Both the PAVB method and the ADA method emphasized making a continuous barrier of the floor, wall and ceiling planes. But they didn't provide a lot of guidance to sealing all the penetrations caused by plumbing, wiring and the like.

The SCS system—The SCS concept is simple-floor sheathing and drywall ceiling/wall surfaces provide 90% of the air barrier, common caulking and sealing techniques handle leaks through penetrations, a methodical approach and a checklist ensure that all potential air leaks have been identified. Further, the concept requires that you identify the appropriate person or trade to perform the caulking and the sealing. The system is being used here in the Northwest, but builders in other parts of the country can easily adapt these details to their own construction methods. Although ours is a heating climate, the same techniques apply to a cooling climate.

Making the system work—Anticipating where the air leaks are likely to be and figuring out how to plug them is the key to making the SCS method work. The emphasis here is on anticipation—you can't insulate and seal a second-floor rim joist if the drywall is already up. The best method I've found for anticipating problems is to spend time with the plans before construction starts. Marking each potential problem on the plans forces me to think methodically about sealing strategies for the whole house. And by doing this ahead of construction, I can order any specialty sealants or gaskets in time to have them ready when needed. The last thing you need is to hold up the project because $100 worth of gasketing is somewhere en route from another state.

The problem with air leaks

The heating load due to air infiltration can make up about a quarter to a third of a home's space-heat requirement. Often in homes built with efficient windows and doors and high levels of insulation in the walls, floors and ceilings, little attention is paid to controlling air leakage. Builders believe they construct quality homes and don't believe that a little infiltration is that big an issue.

The impact of infiltration on a home's heating bill has a lot to do with the energy cost and the climate. Consider an 1,800-sq. ft. house in Portland, Oregon, for example, that is reasonably well insulated. Increasing infiltration from .3 ACH (air change per hour) to about .5 ACH, the annual heating cost would increase by $120, assuming an electric rate of 4.5¢ per kwh. It might cost about $250 extra to build the house to the .3 ACH level, which would yield a simple payback in about two years.

Ventilation and air quality—If major pollution sources are not brought indoors, it's possible for the indoor air quality of the low-leakage home to be better than that of the old home. When the ventilation rate of the home is less dependent on uncontrolled air leakage, it's easier for a small mechanical ventilation system to provide adequate fresh air when and where it's needed. The system can be as simple as high-quality bath and kitchen fans combined with fresh-air inlets.

In the case of some pollutants, such as radon, an airtight floor or basement can reduce the ulterior concentrations. Even sealing a ceiling can reduce the entry of radon into a home by reducing the effective height of the stack effect, which pulls the soil gases into the basement or from the crawl space.

Structural-decay prevention—Reducing air leakage decreases the potential for future structural problems due to moisture-induced decay of the wood framing. As inside air leaks out, it carries with it large amounts of water vapor generated within the home. The amount of moisture admitted in the house through transmission is greater than that admitted through diffusion. (Transmission moves moisture into the house through air leakage. Diffusion moves moisture into the house through solid material.) If the wall and roof sheathings are at a temperature below the dew point, some water vapor will be left behind because of condensation. If this continues over an extended period of time, enough moisture can collect to suport molds, fungi and insects. If the drying potential of the wall or the ceiling assembly is not sufficient to remove the accumulated moisture during yearly cycles, structural damage is likely. —*J. M.*

What to look for—To mark up the plans, start with the obvious. I highlight the exterior envelope of the house (the exterior zone boundary, or EZB). The EZB must be identified because you'll want the air barrier on the inside surface of the EZB. And I've found that it isn't always obvious which walls are outside and which are inside. For example, if there's a stairway to an unheated basement, the stairwell walls ought to be considered outside walls because they are adjacent to an unheated space. Overhangs and cantilevers are other areas that are easily overlooked. They usually get insulated and soffited, but our attempts at air sealing are often not as successful as they might have been had we remembered them before the drywall was hung. Once you've identified the exterior walls of the house, you'll know where the air barrier should be.

Next, determine how you'll provide the air barrier. Normally this will be the drywall on walls and ceilings, and the plywood on the subfloor. Now figure how and when to seal joints in the air barrier. Joints generally fall into two groups: those that require attention before the drywall is installed and those that can be handled after.

Anticipate interruptions—Use the plans to anticipate interruptions, or discontinuities, in the EZB and devise a strategy for dealing with them. Interruptions can include the intersection of partition walls with exterior walls and ceilings, changes in materials, plumbing and wiring penetrations, door and window jambs in exterior walls, HVAC ductwork and the like. The air-sealing checklist names some of the usual culprits (see sample facing page), but you should add to the checklist those details common to the work you do. At this stage it's crucial to figure out where the EZB holes are located and what to do about them and when. This will tell you who should do the work. For example, joints between each sheet in the subfloor must be sealed, and the best time to do this is as the subfloor is going down. That implies the use of a weather-resistant sealant It also implies that carpenters will do the work. It is important to decide who should plug each hole in the envelope. If you fail to assign responsibility, the work probably won't get done.

WORKING OUT THE DETAILS

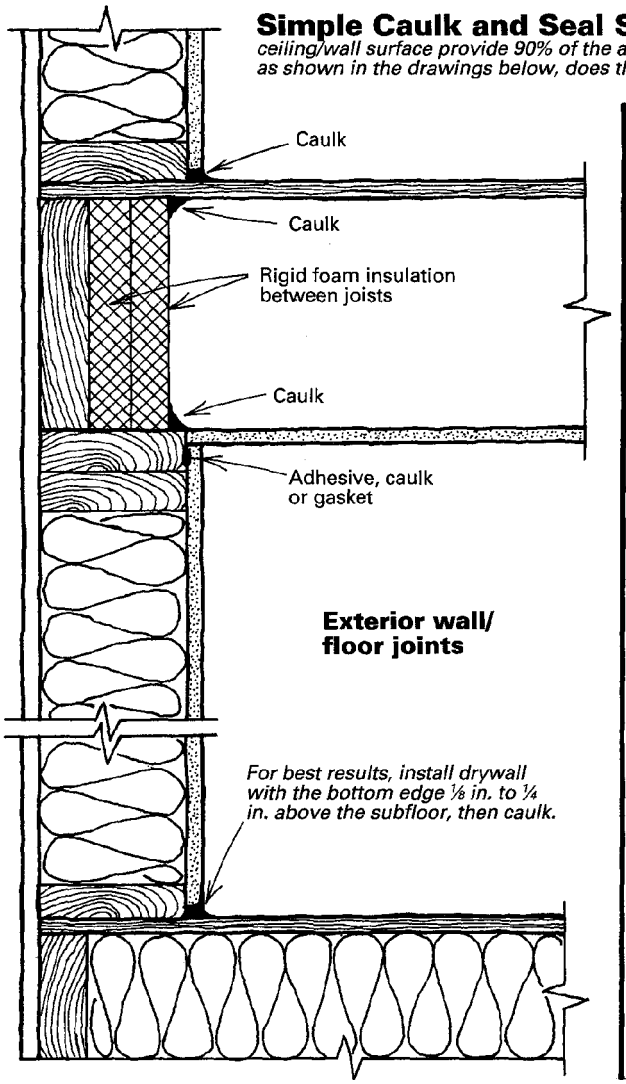
Here's what you'll need to do when sealing new houses. Bear in mind, however, that not every house can be handled the same way.

Floors—Floors over crawl spaces are easiest to seal while the subfloor is being laid. Most builders use construction adhesive and mechanical fasteners to install a plywood or OSB (oriented strand board) subfloor. This is an opportunity to provide an airtight subfloor.

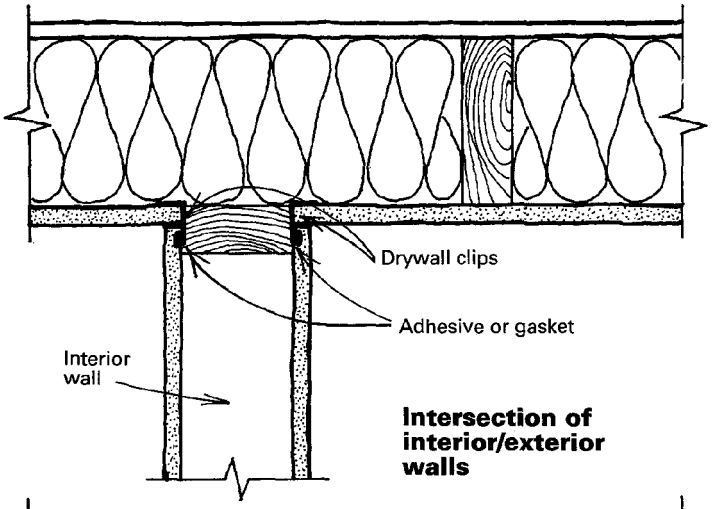
To seal the short dimension of the sheet, apply a continuous bead of glue on the joist at the butt joint. To seal the long dimension, add a bead of adhesive to the bottom side of the tongue before laying the sheet down. This will ensure that any excess glue will squeeze out on the underside

Simple Caulk and Seal System

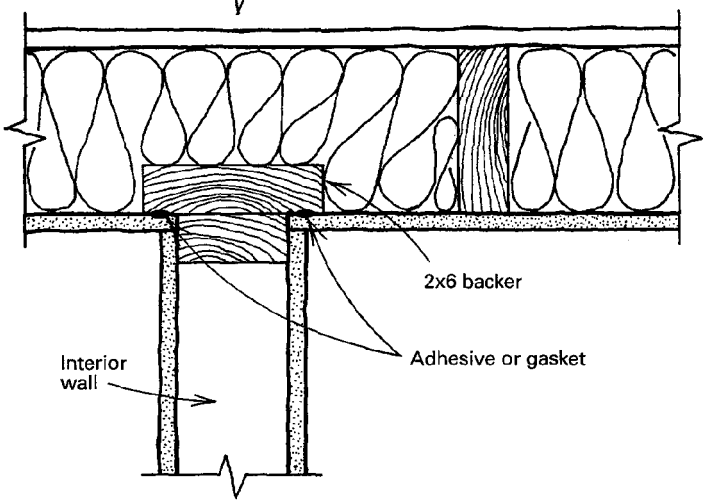
The floor sheathing and the drywall ceiling/wall surface provide 90% of the air barrier. Careful caulking and sealing of exterior walls, as shown in the drawings below, does the rest.



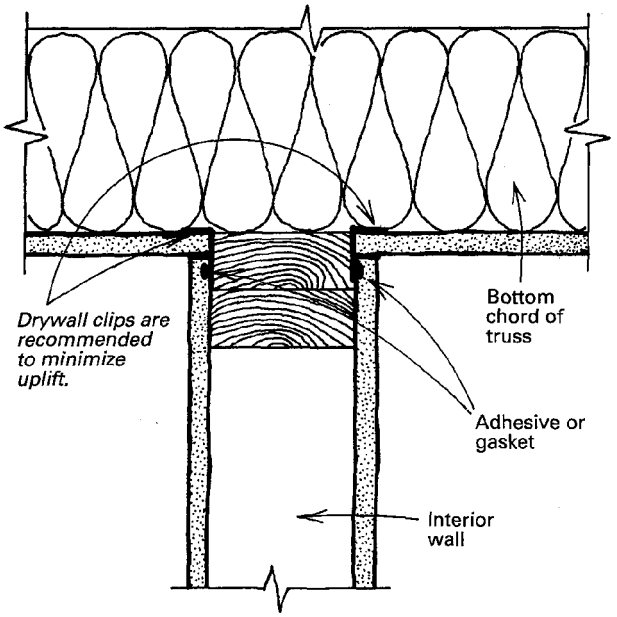
Exterior wall/ floor joints



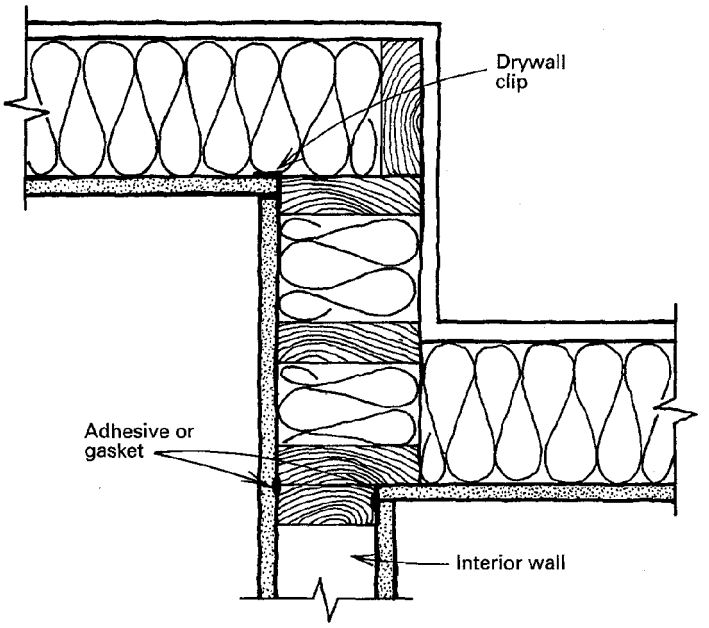
Intersection of interior/exterior walls



Intersection of interior wall/ exterior ceiling



Intersection with a corner



Drawings: Jeff Bellentuono

when the sheets are brought together, not on top where the glue will interfere with floor finishes.

With floors over basements and on the second story of a house, the key air-leakage site is the rim-joist area (drawings facing page). These floors can be sealed after framing. The best approach is to handle the insulation, the air sealing and the moisture diffusion at the same time. First, seal the joint between the mudsill and the foundation with a compressible gasket or caulk. On a first floor over a heated basement or on a second floor, install rigid insulation against the inside of the rim joist and caulk around all edges. For a two-story home, seal between the top plate of the lower wall and the drywall.

Exterior wall/floor joints—Typically, builders use caulks or gaskets under the bottom plate of an exterior wall, then apply another gasket or drywall adhesive between the bottom plate and the drywall. With the SCS system, you just seal the joint between the subfloor and the interior wall covering, which usually is drywall (drawings facing page). Sealing this joint eliminates having the framing crew deal with an additional step while they're trying to put up the building shell. It also makes it possible to do the sealing work after the drywall is up and the home is weathertight. This step can be postponed until just before the finish floors go down.

Intersection of interior/exterior walls—To avoid air leaks in partition walls, you must seal their intersections (drawings facing page). This can be done after framing is completed and the shell insulated. Seal the drywall to the last stud in the interior partition with drywall adhesive. The adhesive should run from the subfloor to the top of the plate. An alternative is to install a length of compressible gasket between the drywall and the last stud. The gasket can be applied at once, before the drywall application, or a worker can do a room at a time ahead of the drywall crew.

Intersections of interior wall/exterior ceilings—This connection is sealed like the wall intersection. Seal the partition drywall to the top plate of the partition wall with a bead of adhesive or a compressible gasket (drawings facing page). This effectively seals off the interior wall cavities from the attic or the roof above.

Forced-air heating systems—The design and installation of the heating system has a major impact on successfully controlling air infiltration or exfiltration. A home with an airtight envelope may still have unacceptably high infiltration levels if the heating system is not appropriate. The following guidelines will minimize the impact of HVAC systems on the air-leakage rate.

Try to get the heating plant and the ductwork inside the EZB. Any leaks in the system will provide heat to the home, and outside air cannot be pulled into the return side. This might mean putting the mechanical room on the first floor rather than parking it in the basement. Dropped soffits can provide space for ducts.

If ductwork must be run outside the insulated shell, make sure ducts are well sealed. Seal the joints between the lengths of duct, as well as the metal seams along the lengths of the duct and any crimped edges on plenum boxes or register boots. Use high-quality tape or a sealant specifically designed for ductwork (see sidebar above). Remember, metalwork often has a coating of oil on it from the fabrication process. You can remove the oil using a rag dipped in mineral spirits.

Design the heating system so that the supply and return portions are in balance. This may mean using more returns than normal. Also, bedroom doors should be undercut a minimum of ¾ in. if there is no return in the bedroom. Other options to allow for return air flow are to use louver doors or open transoms to the hallway. □

Jim Maloney is a resource planner for the Eugene Water & Electric Board in Eugene, Ore. *The author acknowledges the support of the Bonneville Power Administration.*

Sealing leaks: what to use

There are five types of materials used to stop leaks in the building envelope. The following list is a sampling of what's available; it is not a comprehensive list. However, it includes products that have worked for me. —*J. M.*

Adhesives
Adhesives bond materials together and limit or eliminate air leaks. They are best used when there won't be any differential movement between the materials being joined.

Henry 113 Drywall Stud Mastic, WW Henry Co., 5608 Solo St., Huntington Park, Calif. 90255; (213) 583-4961.

Lumberlock All Weather Construction Adhesive, Miracle Adhesives Corp., 2230 Howell St., Bellmore, N. Y. 11710; (516) 826-0021.

PL200 and PL500 Construction Adhesive, ChemRex, Inc., Contech Brands, 7711 Computer Ave., Minneapolis, Minn. 53435; (612) 835-3434.

Caulks and sealants
Caulks and sealants bridge the gap between dissimilar materials (see *FHB* #61, pp. 36-42).

Air-Lock Water-based Duct Sealant, RectorSeal Corp., P. O. Box 14669, Houston, Texas 77221; (800) 231-3345.

MD 35 Acrylic Rubber Sealant with Silicone, Macklanburg-Duncan, P. O. Box 25188, Oklahoma City, Okla. 73125; (800) 654-8454.

Magic Seal Siliconized Acrylic Latex, Magic Seal Corp., 1000 Executive Pky., Creve Coeur, Mo. 63141; (314) 469-9082.

Sonolastic NP-1 Urethane Sealant, Sonneborn Building Products, Div. of ChemRex, Inc. (address above).

Sikaflex la Urethane Sealant, SIKA Corp., Construction Products Div., Polito Ave., Lyndhurst, N. J. 07071; (201) 933-8800.

Gaskets
Gaskets, preformed elastomeric materials, provide air-barrier continuity in the seams between materials. They must be compressed to function because they usually have no permanent adhesion to the surfaces they lie between. Because they return to their original dimension after compression, gaskets are used when joint movement is expected. Gaskets also seal the joint between drywall and wood.

ADA Gasket, Resource Conservation Technology, 2633 North Calvert St., Baltimore, Md. 21218; (410) 366-1146.

P Strip Weatherstrip, Whole Energy & Hardware, 1620 Audubon Road, Chaska, Minn. 55318; (800) 544-2986.

Sure Seal and Ultra Seal Gaskets, DENARCO Sales Co., 12710 Idlewilde, White Pigeon, Mich. 49099; (616) 641-2206.

Foams
Expanding foams seal openings larger than ½ in. wide, though some care is required when filling deep holes. Nonexpanding foams work well in gaps that cannot otherwise be sealed successfully, such as the shim space around windows and doors. The following companies offer foams and foam-application systems:

Whole Energy & Hardware (address above).

H1LTI, Inc., P. O. Box 21148, Tulsa, Okla. 74121; (800) 879-8000.

FOMO Products, Inc., 2775 Barber Road, P. O. Box 1078, Norton, Ohio 44203; (216) 753-4585.

Todol Products, Inc, 20 Charles St., Natick, Mass. 01760; (508) 651-3818.

Sheet materials
Where holes are irregular or where there is no backing to apply foam against, such as around plumbing penetrations, use a small sheet of elastic material with a hole cut out for the penetration. Pieces of ⅛-in. thick rubber cut from old truck inner tubes work well. The following companies offer sheet products:

Resource Conservation Technology, Inc. (address above).

Whole Energy & Hardware (address above).